Simulation on beam loss from radiative Bhabha process

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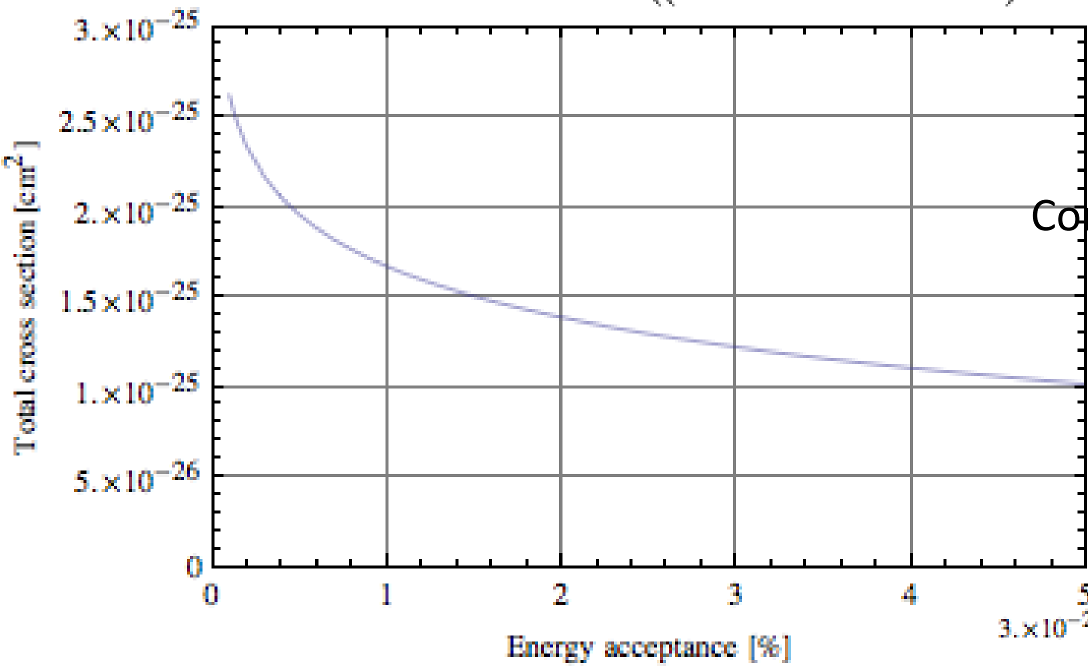
KEK

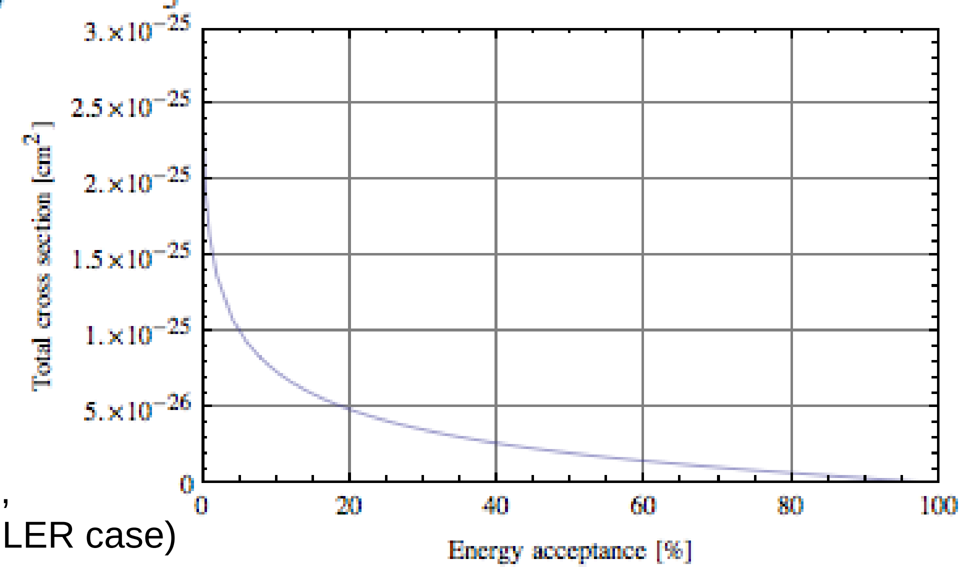
CROSS SECTION AND LIFETIME

Total cross section

$$\sigma[\epsilon, a] = \frac{16}{3}\alpha r_e^2\left(\left(-\frac{3\epsilon^2}{8}+\epsilon+\log\left(\frac{1}{\epsilon}\right)-\frac{5}{8}\right)\left(\log\left(\sqrt{2}\ a m_e\right)+\frac{\gamma_e}{2}\right)+\frac{1}{4}\left(-\frac{2\epsilon^2}{3}+\frac{13\epsilon}{3}+\frac{13}{3}\log\left(\frac{1}{\epsilon}\right)-\frac{17}{6}\right)\right)$$



Correction from finite beam size is included.



$\sigma(\varepsilon>1.5\%) = 1.55 \times 10^{-25}\ cm^2$

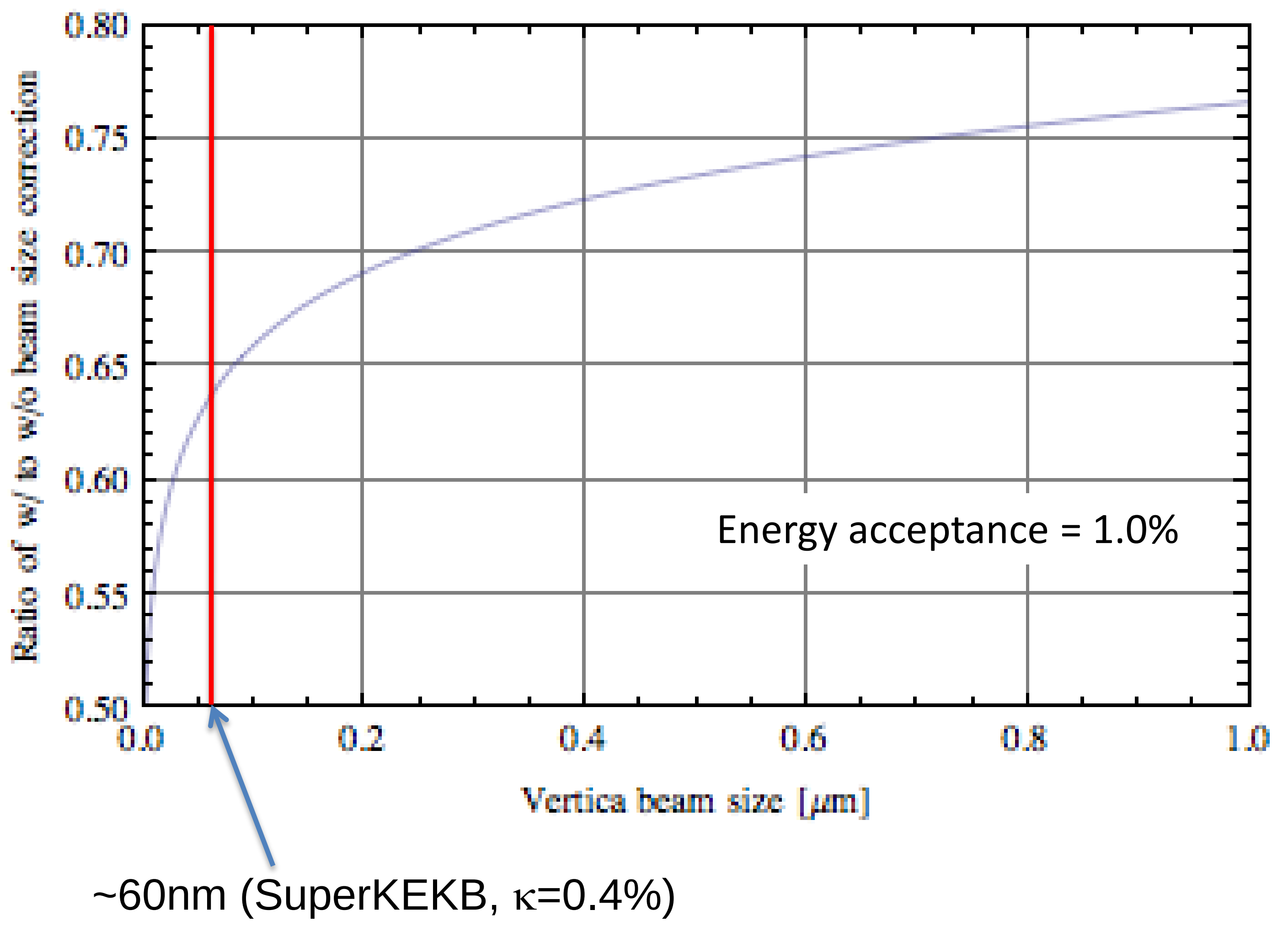
$\sigma(\varepsilon>5.0\%) = 1.05 \times 10^{-25}\ cm^2$

$\sigma(\varepsilon>20\%) = 0.51 \times 10^{-25}\ cm^2$

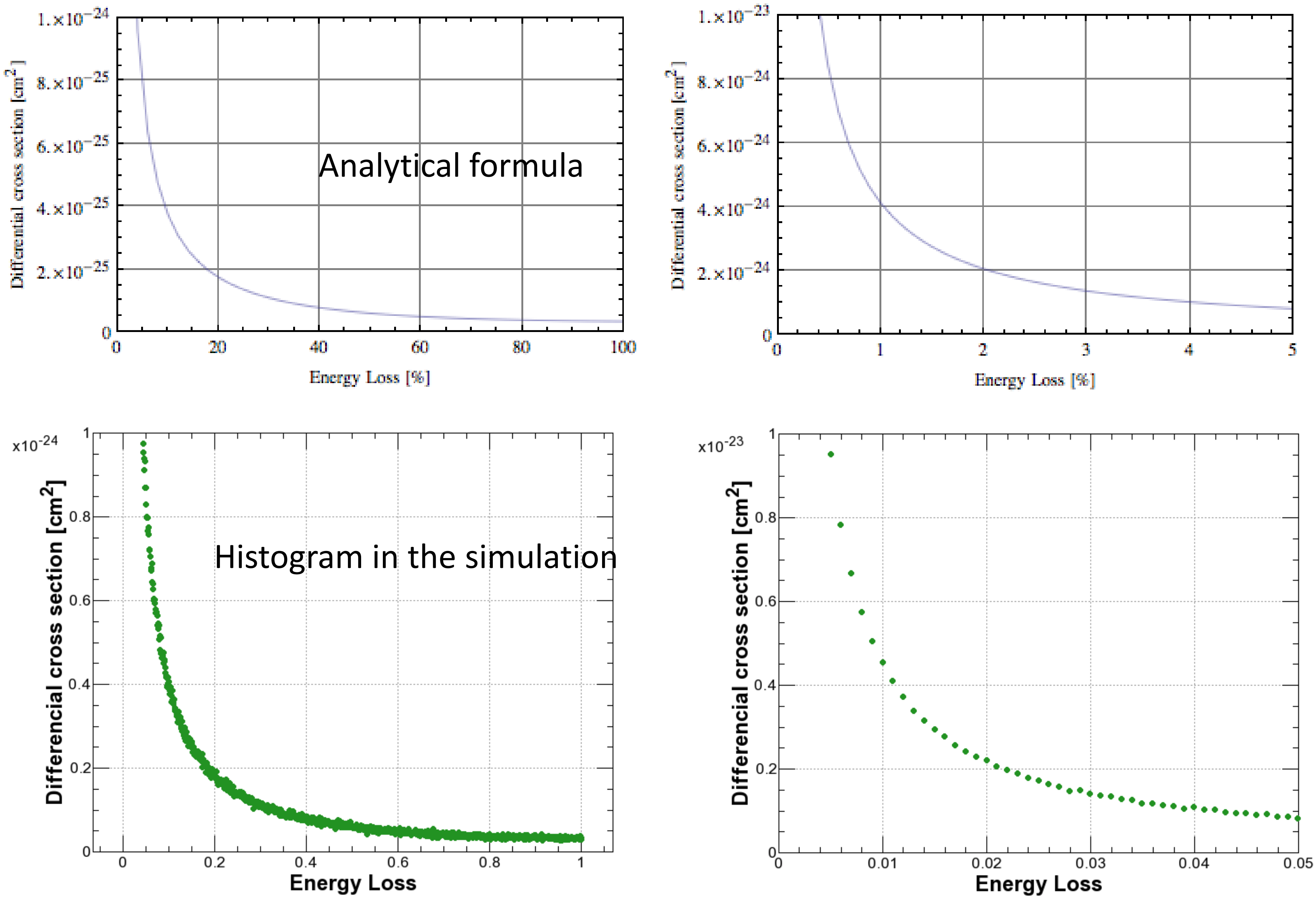
$\sigma(\varepsilon>50\%) = 0.20 \times 10^{-25}\ cm^2$

Assuming particles are lost with energy loss of $\varepsilon>1.5\%$,
Beam lifetime = 30.15 min. ($L=8\times10^{35}$ /cm^2/s, Ib=3.6A, LER case)
Loss rate 1.99mA/s

Correction for cross section due to finite beam size



Differential cross section



Beam Loss Processes

	LER beam lifetime
Touschek effect	~10 min.
Beam-Gas Coulomb scattering	~30 min.
Radiative Bhabha	~30 min.

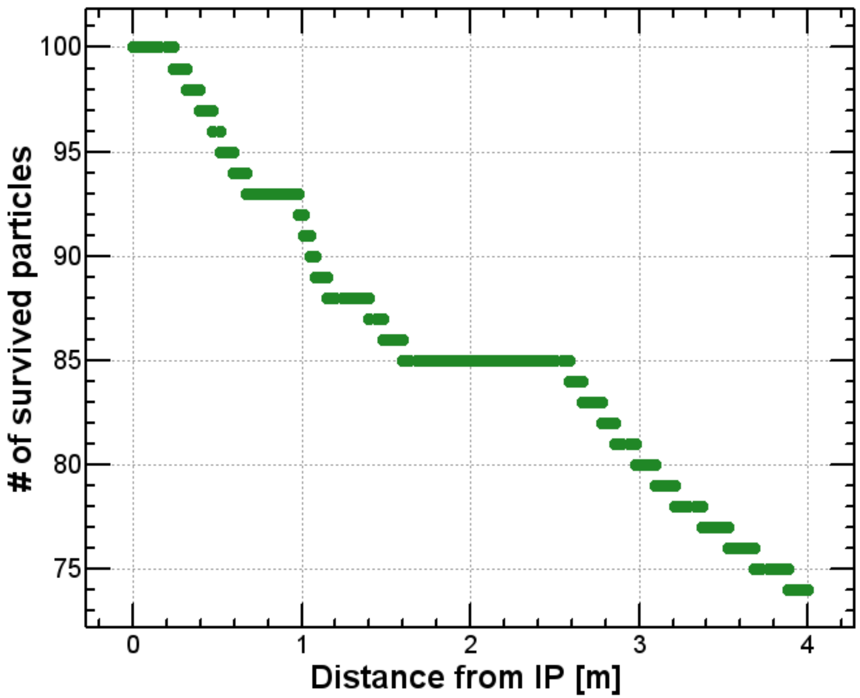
METHOD OF SIMULATION

Beam loss simulation (radiative Bhabha) recent update

- Physical aperture
  - QC1 (final focus quad) 10.5mm -> 13.5mm
  - Movable collimators for the purpose of reducing the Touschek and beam-gas background
- Lattice
  - Latest lattice: lerfqlc1633_3(LER), herfqlc5605(HER)
- Generator
  - BBbrems + beam sizes
  - Handmade generator to reproduce the energy loss distribution of the analytical formula + beam sizes
- Tracking simulation
  - Using SAD (1 turn tracking)

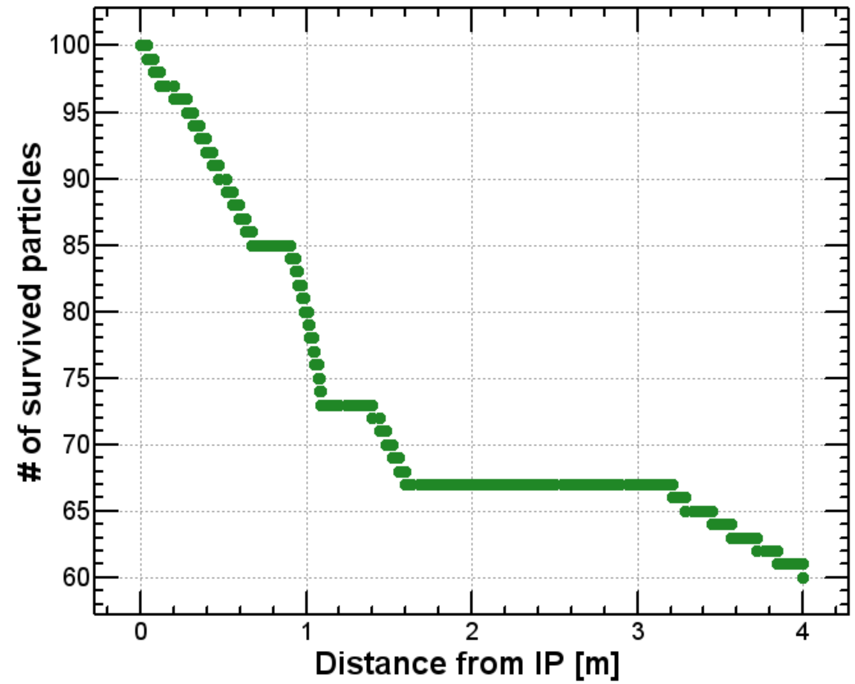
Beam Loss within 4m from IP
One turn tracking with a large energy deviation
(100 particles $\Delta p/p$ =0, -1, …,-99%)

No COD



Particles are lost, when they lose more than 75% of their energy.

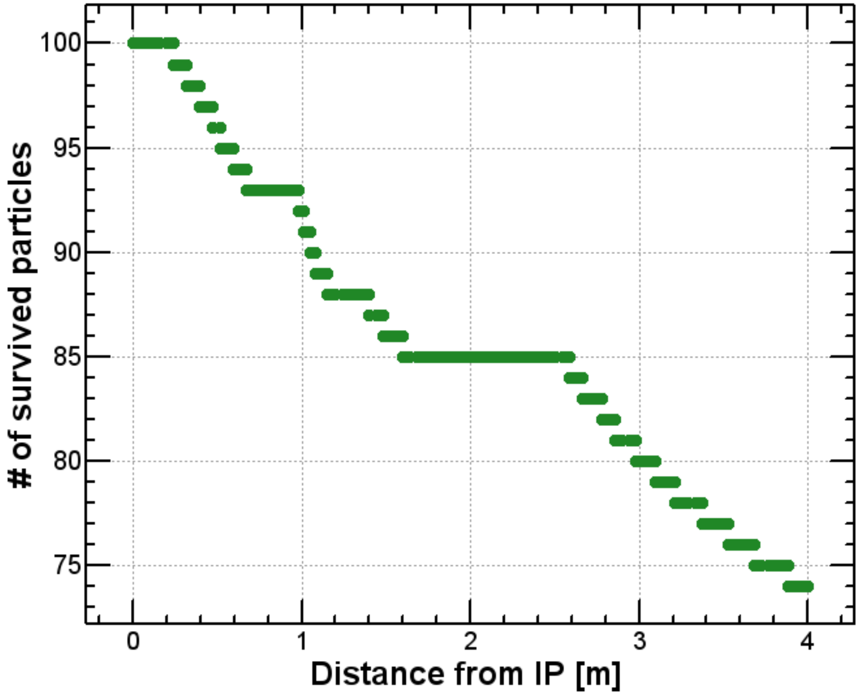
With COD (iBump x and y)



Particles are lost, when they lose more than 60% of their energy.

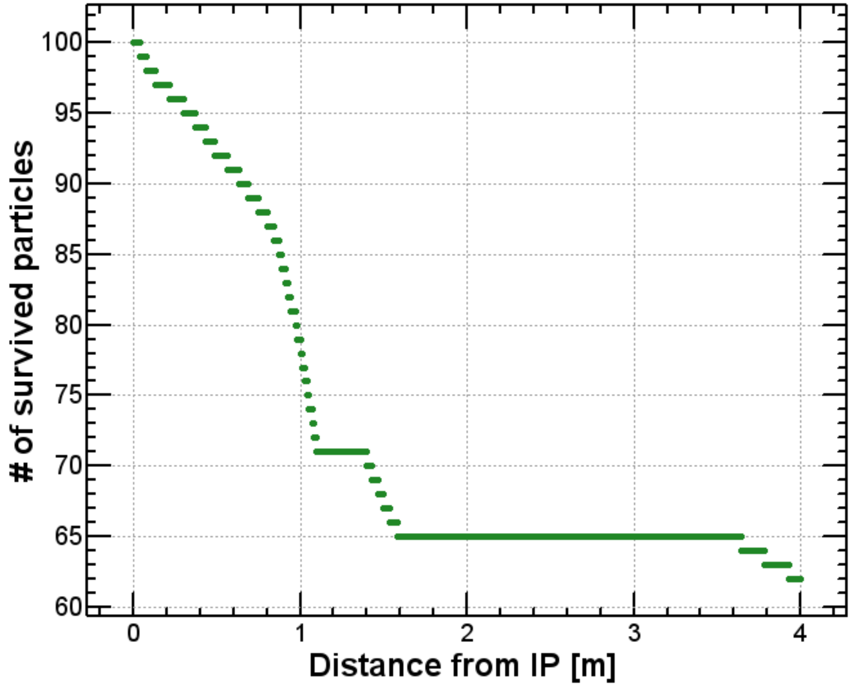
Beam Loss within 4m from IP
One turn tracking with a large energy deviation
(100 particles $\Delta p/p$ =0, -1, ...,-99%)

lerfqlc_1604



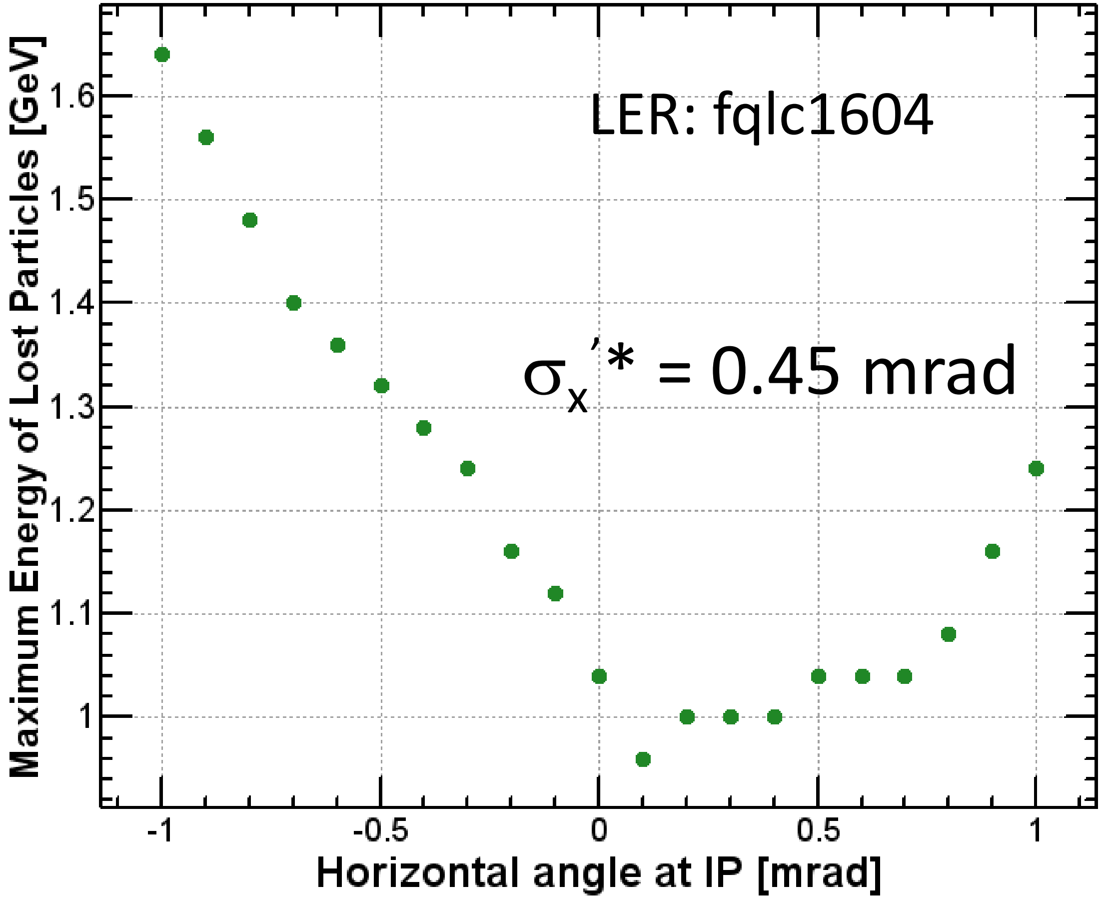
Particles are lost, when they lose more than 74% of their energy.

lerfqlc_1633_3



Particles are lost, when they lose more than 62% of their energy.

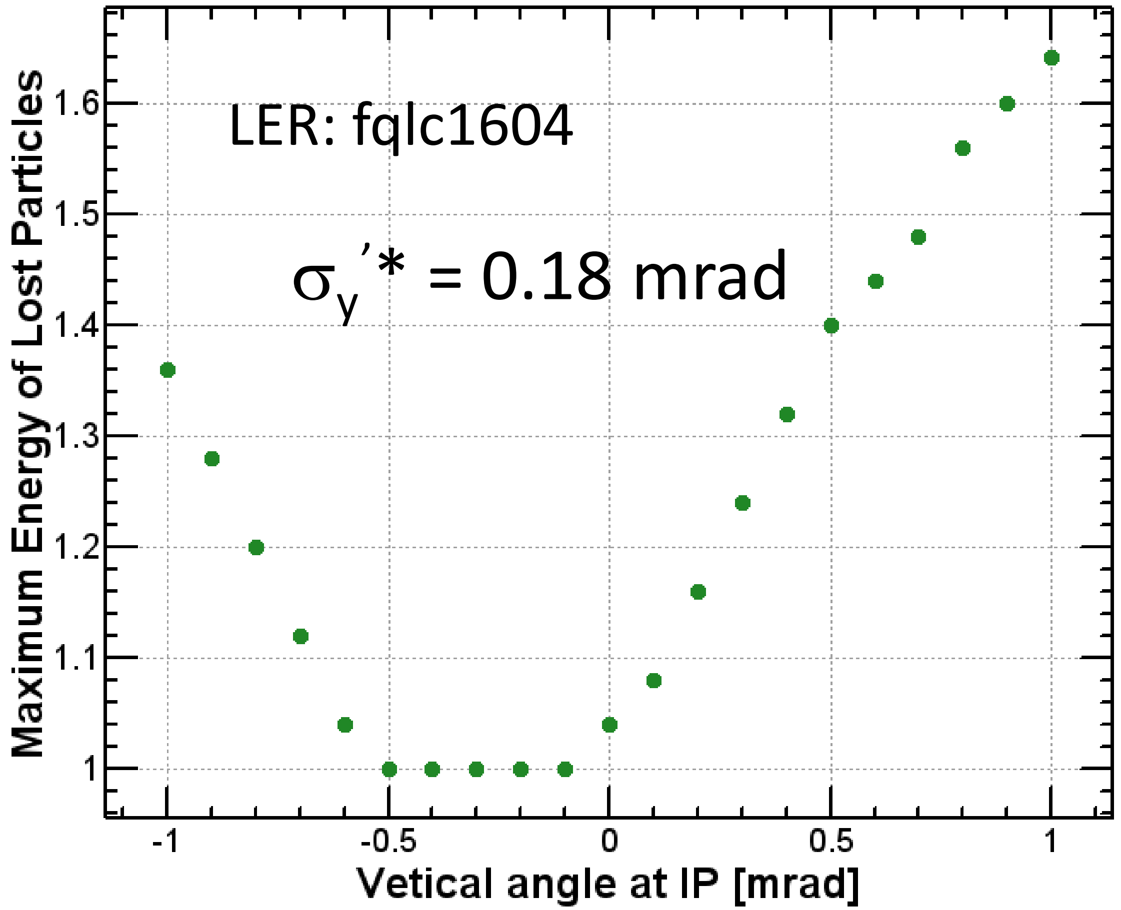
Maximum energy of survived particle at s = 4m



Effect of horizontal angle at IP

It is importance to consider the angular distribution of beam.

Maximum energy of survived particle at s = 4m



Effect of vertical angle at IP

IP machine parameters

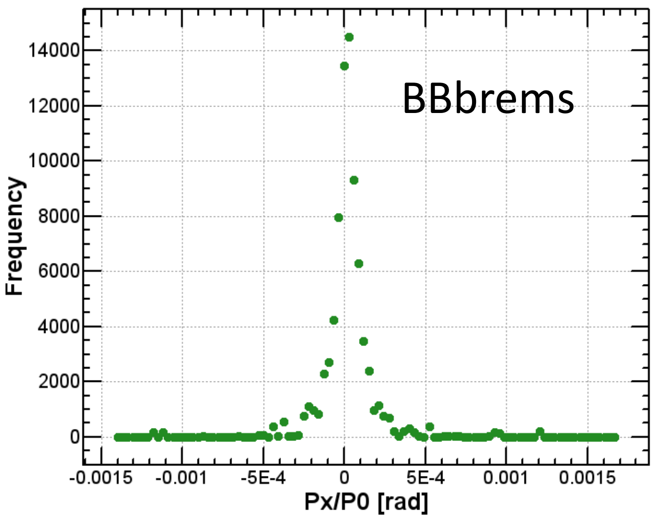
	KEKB		SuperKEKB	
	LER	HER	LER	HER
ε_x	18nm	24nm	3.2	5.0
ε_y	0.15nm	0.15nm	8.6pm	13.5pm
κ	0.83 %	0.62%	0.27%	0.25%
β_x*	120cm	120cm	32mm	25mm
β_y*	5.9mm	5.9mm	0.27mm	0.31mm
σ_x*	150μm	150μm	10μm	11μm
σ_x'*	120μrad	120μrad	450μrad	320μrad
σ_y*	0.94 μm	0.94μm	48nm	56nm
σ_y'*	0.16mrad	0.16mrad	0.18mrad	0.22mrad
iBump horizontal offset		+/- 500μm		+/- 30μm?
iBump vertical offset		+/- 150μm		+/- 7.5μm?
iBump vertical angle		+/- 0.4mrad		+/- 0.4mrad?

Generator

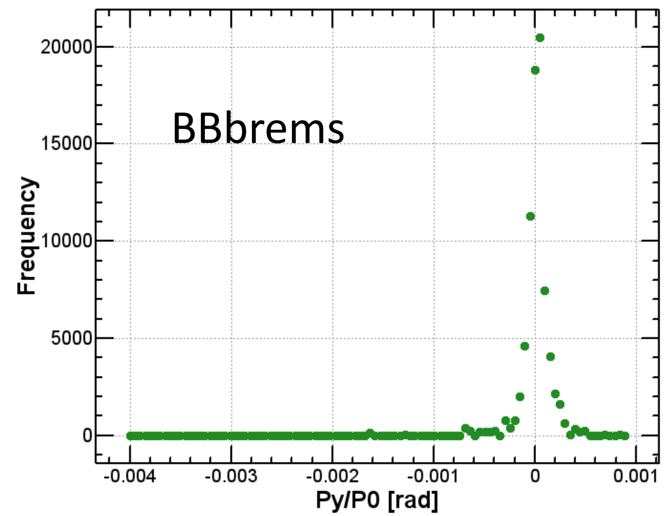
- Handmade generator
  - Beam sizes
  - To reproduce the energy loss of the analytical formula
- BBbrems
  - Distribution of scattering angles are automatically included.
  - Spread of particle distribution corresponding to beam sizes is artificially added.
  - Two different sets of distributions
    - E_lab < 2 GeV (~80,000 events LER, ~27,000 events HER)
    - E_lab < 3 GeV (~1,800,000 events LER, 270,000 events HER) Simulation is on the way

Scattering angle distribution (BBbrems)

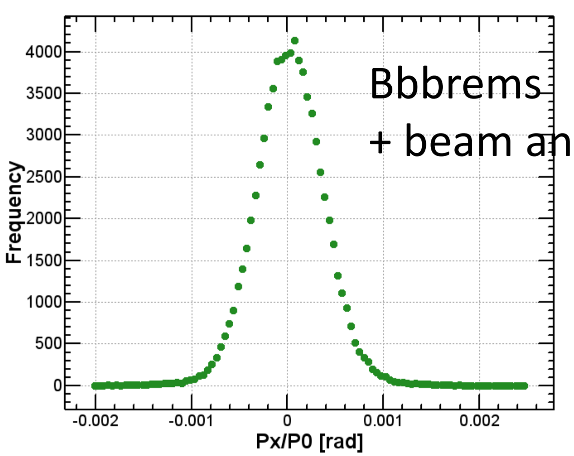
sigma = 1.7039168E-4 cf. $\sigma_x{'}^* = 0.45$ mrad



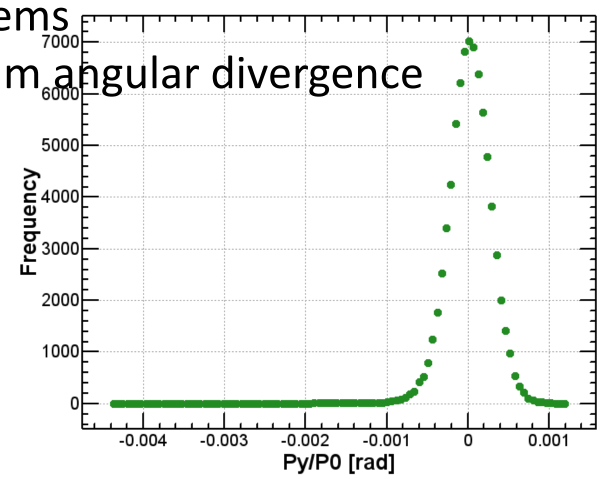
sigma = 1.694376E-4 cf. $\sigma_y{'}^* = 0.18$ mrad



sigma = 3.6299968E-4

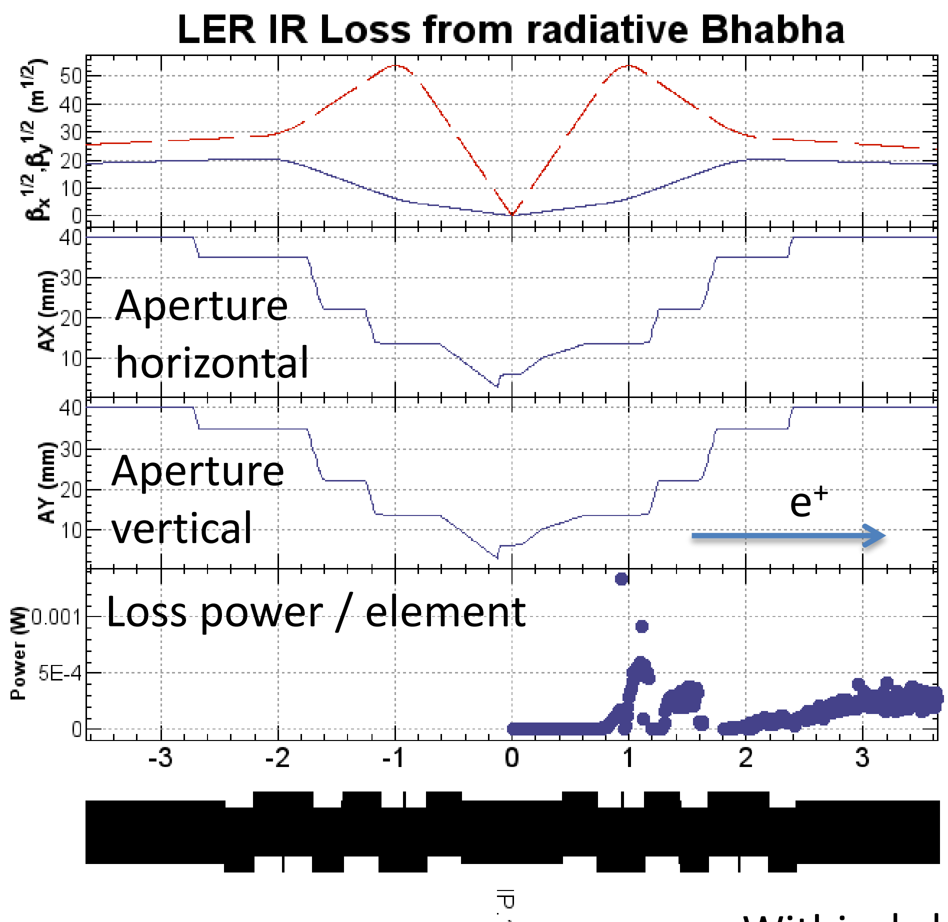


sigma = 2.7904864E-4



SIMULATION RESULTS

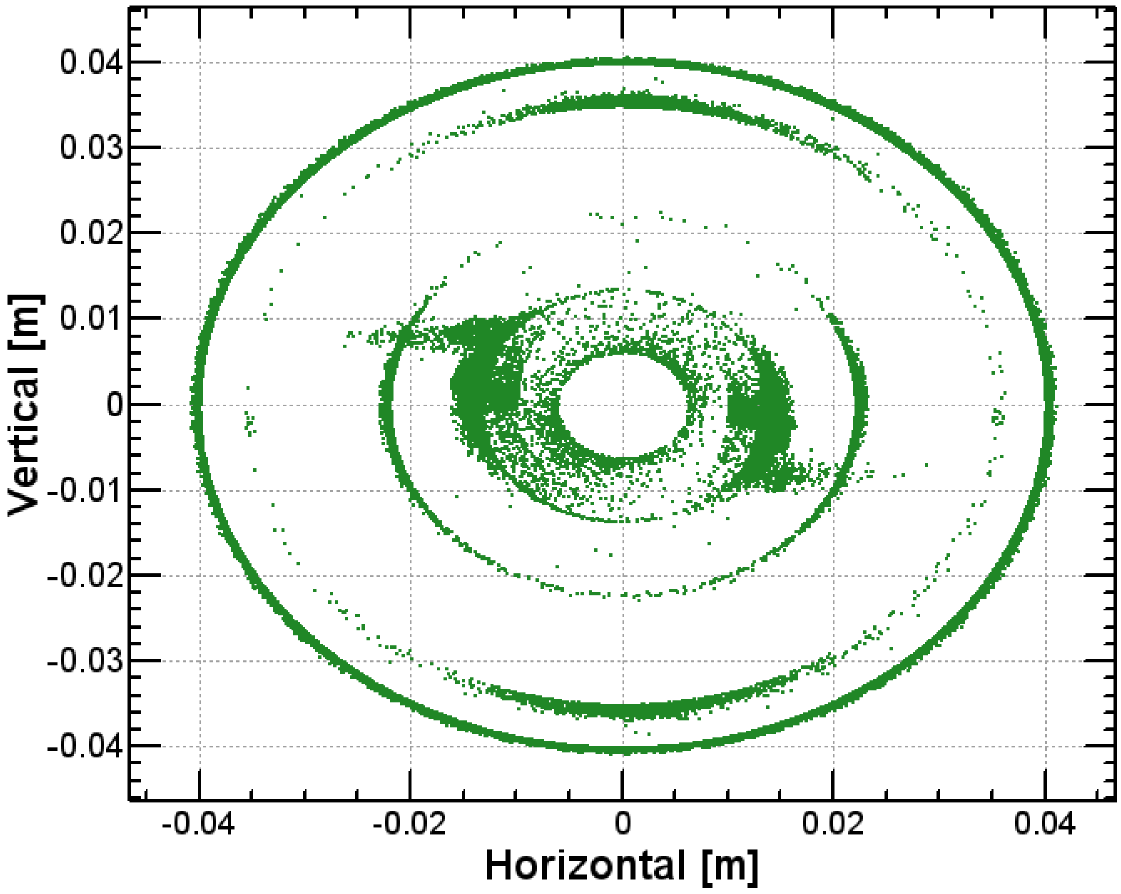
LER: Data of BBbrems (10/38 of total events)



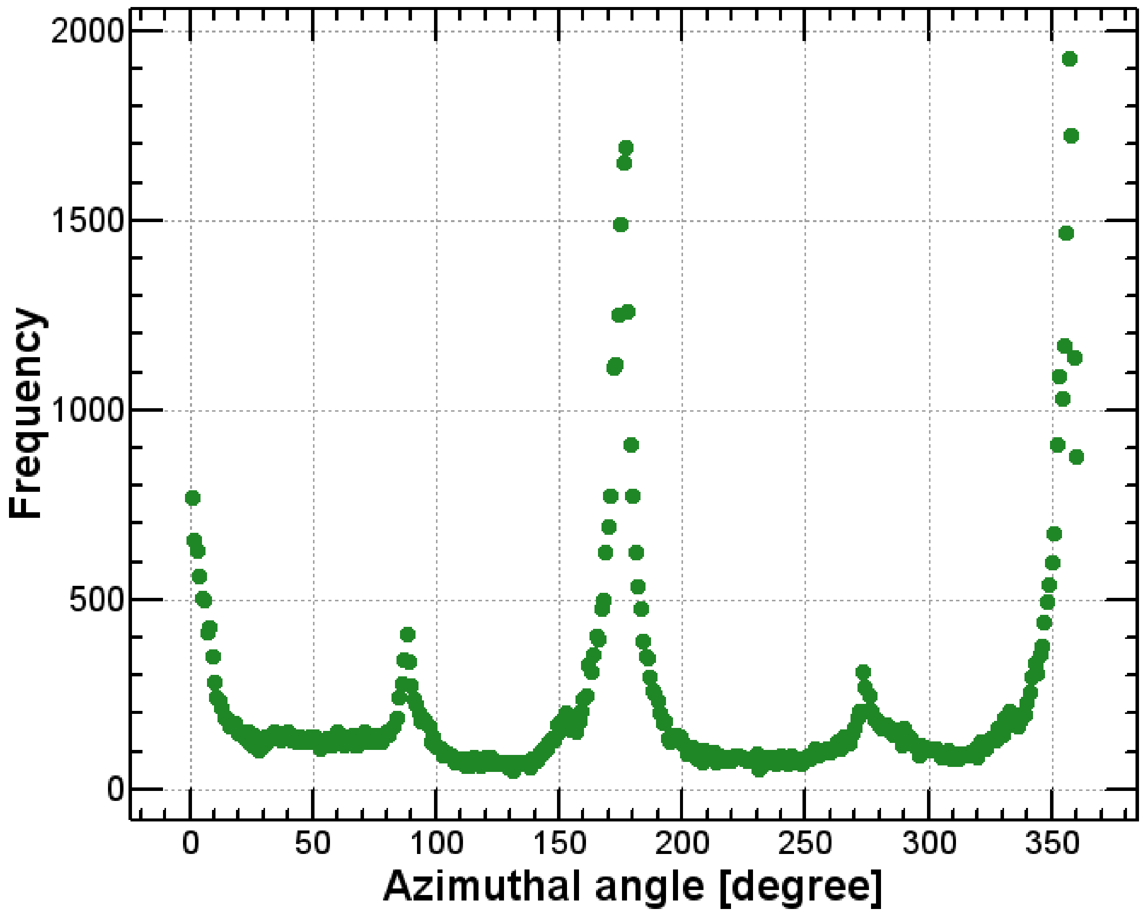
CoordinateBeamLoss2012_2_6_18_2_39.dat

Within |z|<4m,
Loss rate: 6.0 GHz
Power loss: 0.56W
Effective loss rate: 0.87GHz (4GeV)

Transverse coordinates of lost particles

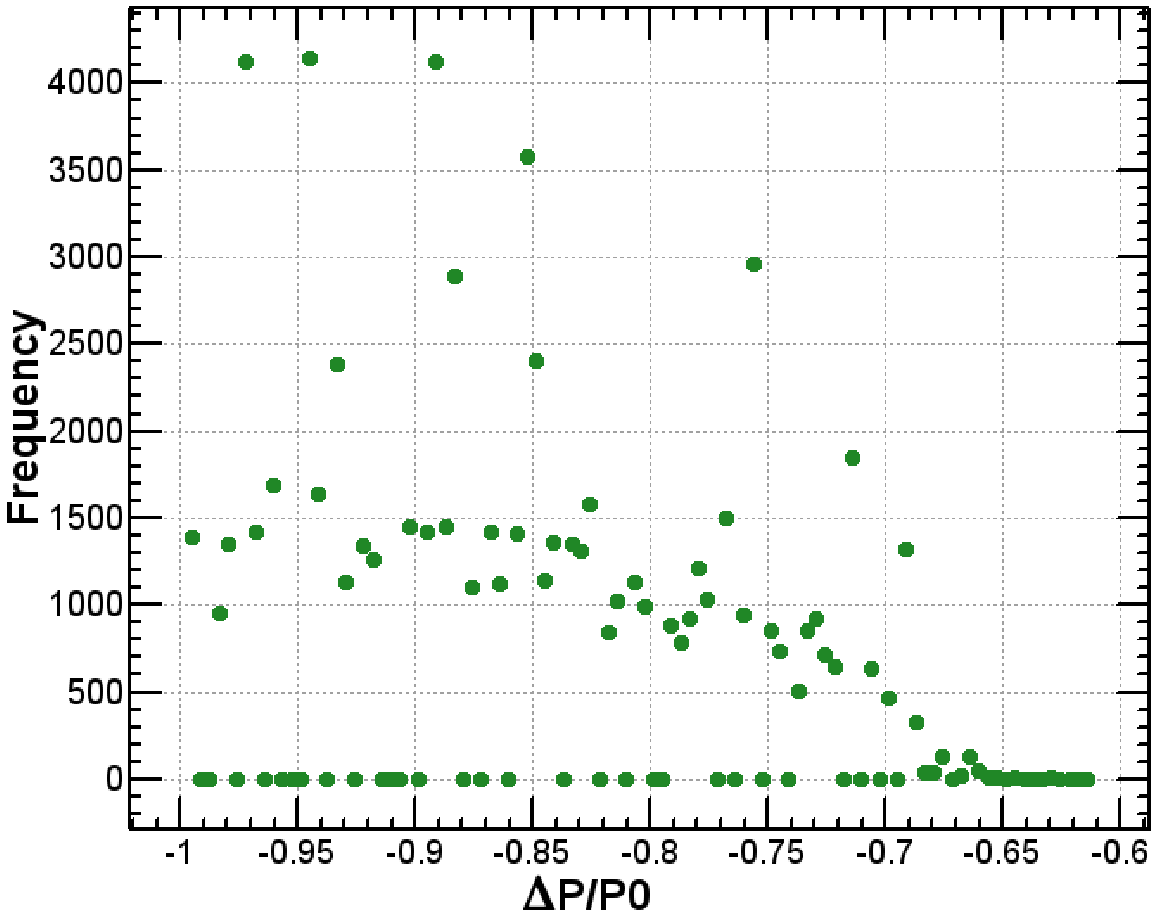


Angular distribution of lost particles



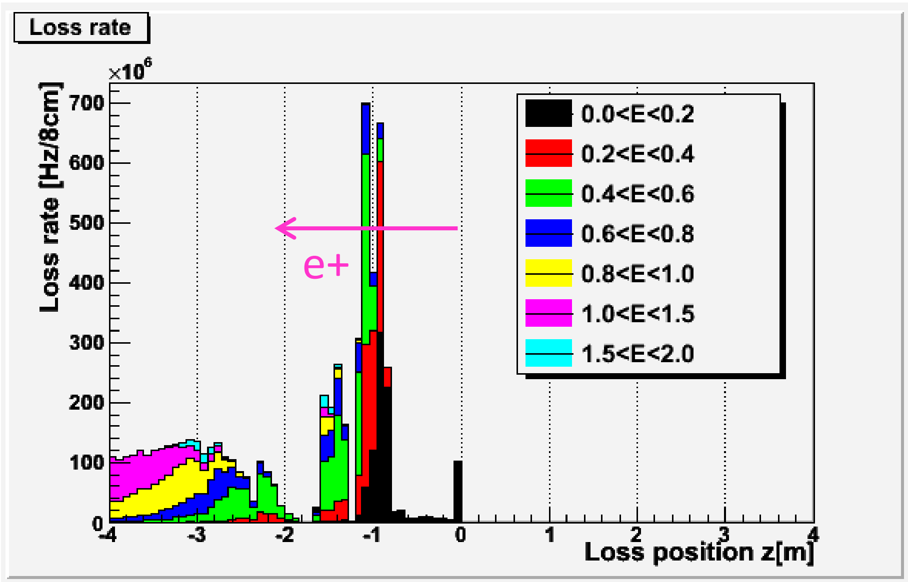
Zero denotes outside of horizontal plane.

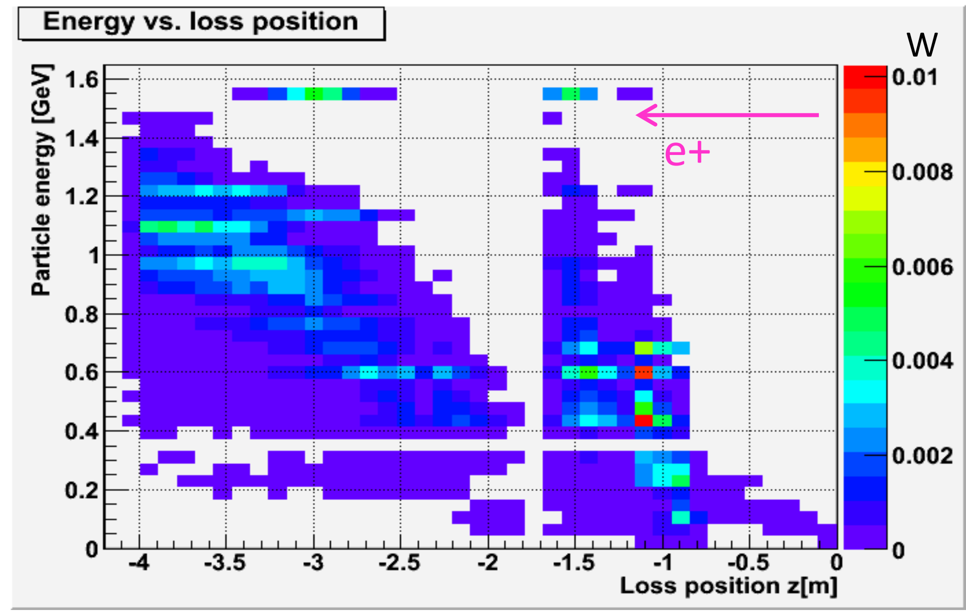
Energy distribution of lost particles

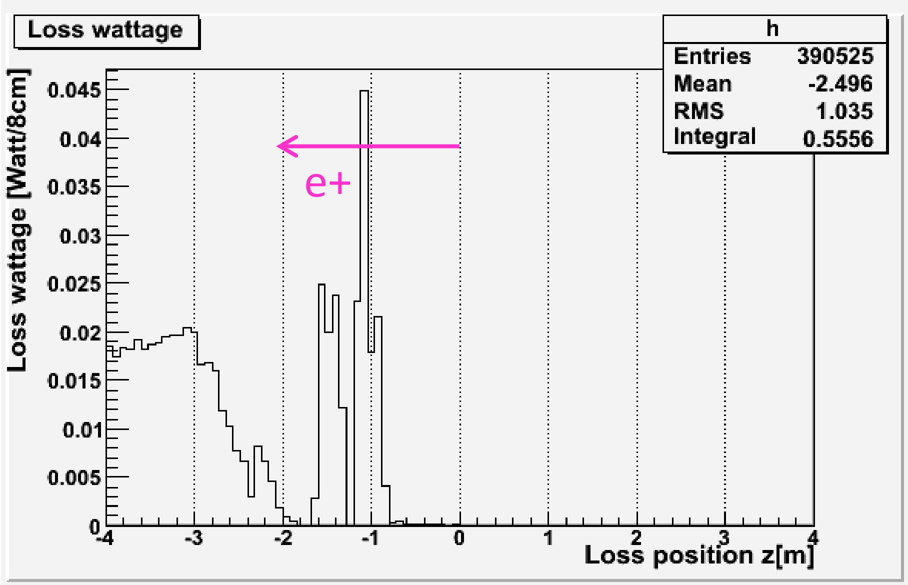


H. Nakayama

Radiative Bhabha LER





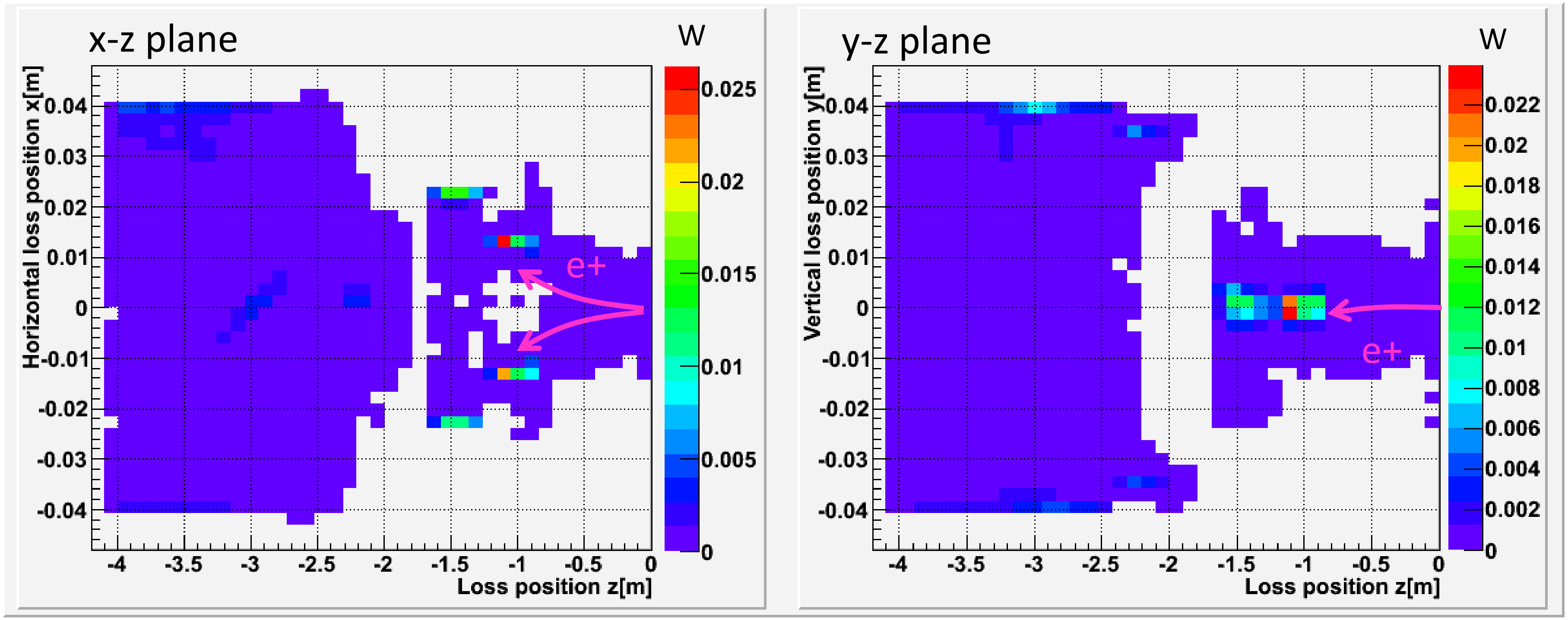


Within |z|<4m,
loss rate: 6.0 GHz(0~1.4GeV)
loss wattage: 0.55 W
(Equivalent to 0.86GHz of 4GeV e-)

Loss wattage: we assume all energy of beam particle is deposited at the loss position.

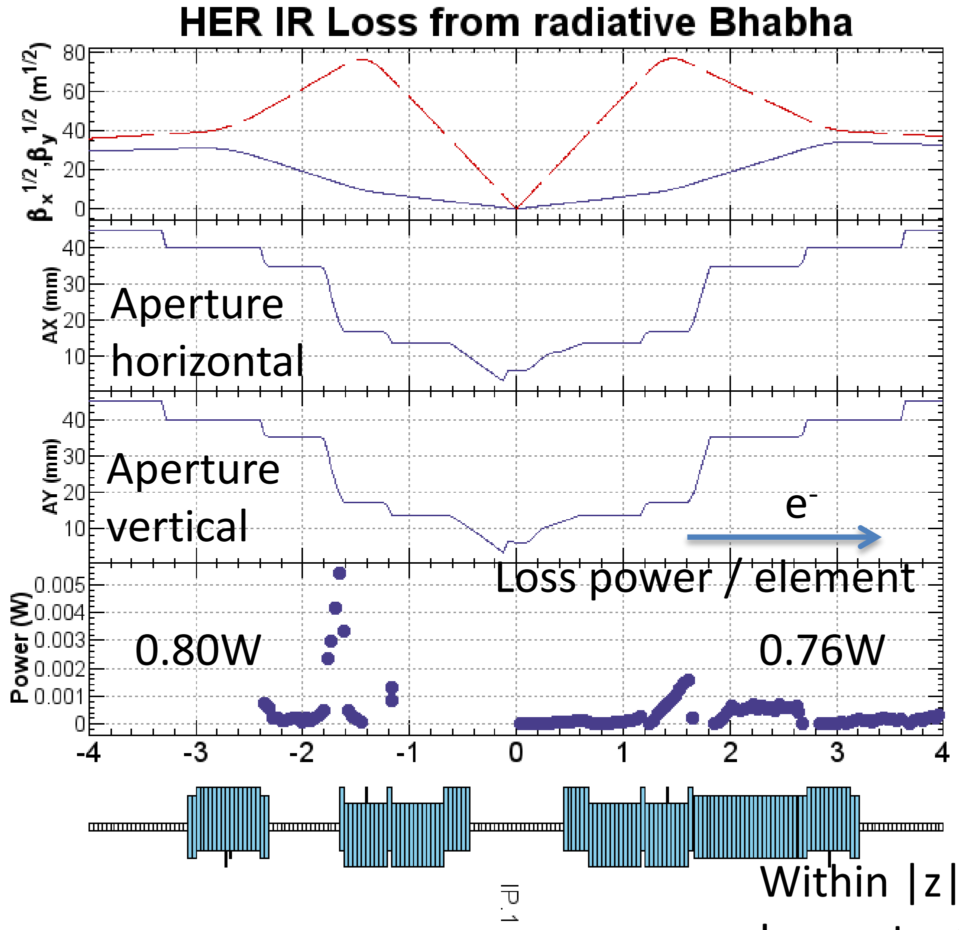
H. Nakayama

Radiative Bhabha LER (contd.)



Horizontally lost at z=-1m

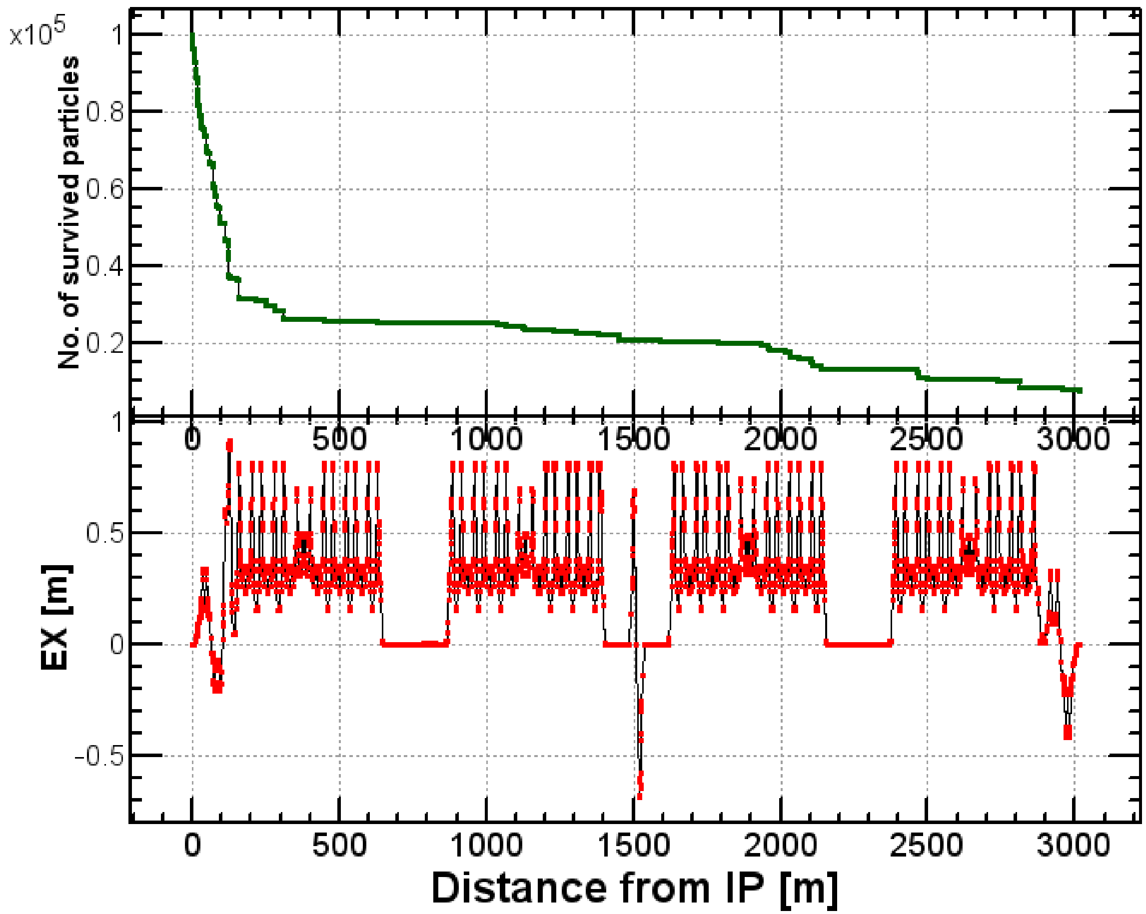
HER handmade generator



CoordinateBeamLoss2012_2_7_14_54_47.dat

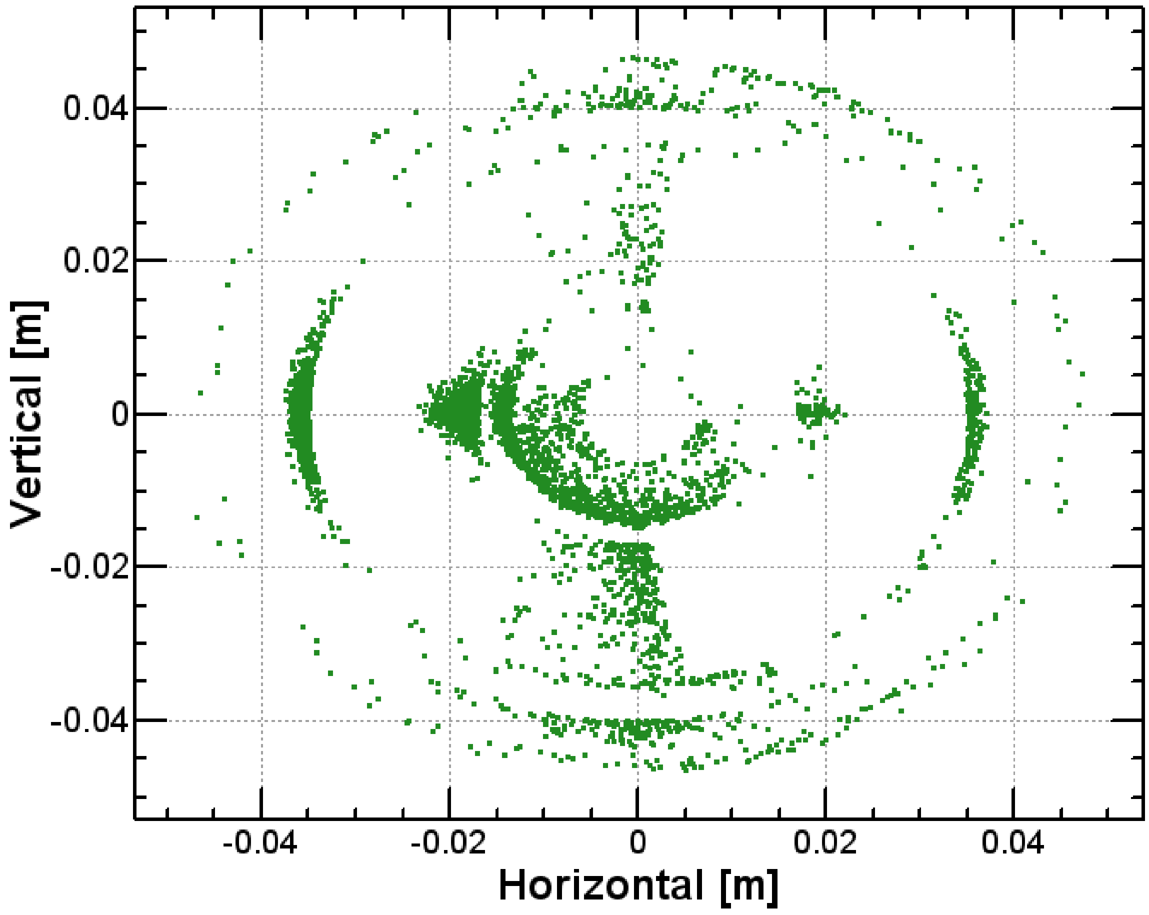
Within |z|<4m,
Loss rate: 6.5 GHz
Power loss: 1.56W
Effective loss rate: 1.4GHz (7GeV)

HER: handmade generator
0.01 < ΔE < 1

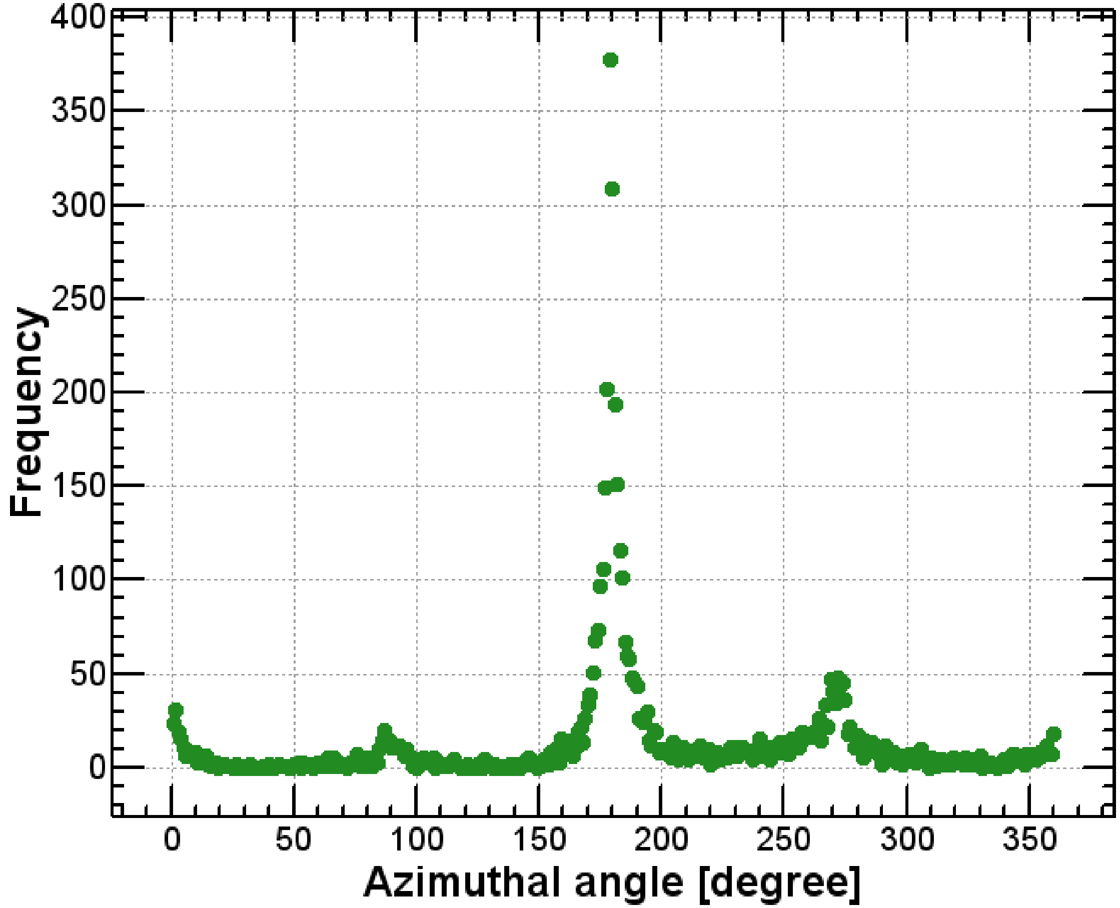


CoordinateBeamLoss2012_2_7_14_54_47.dat

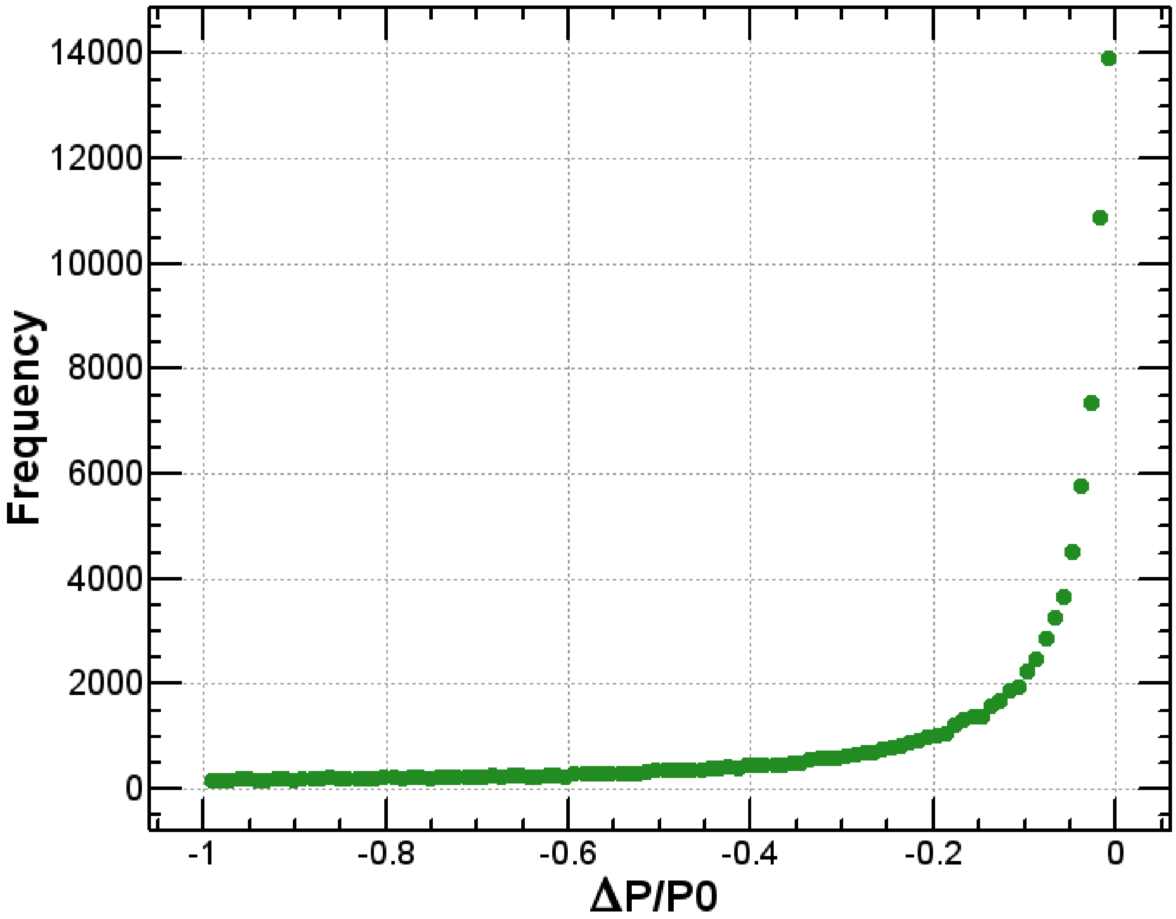
Transverse coordinates of lost particles -4m < s < 4m



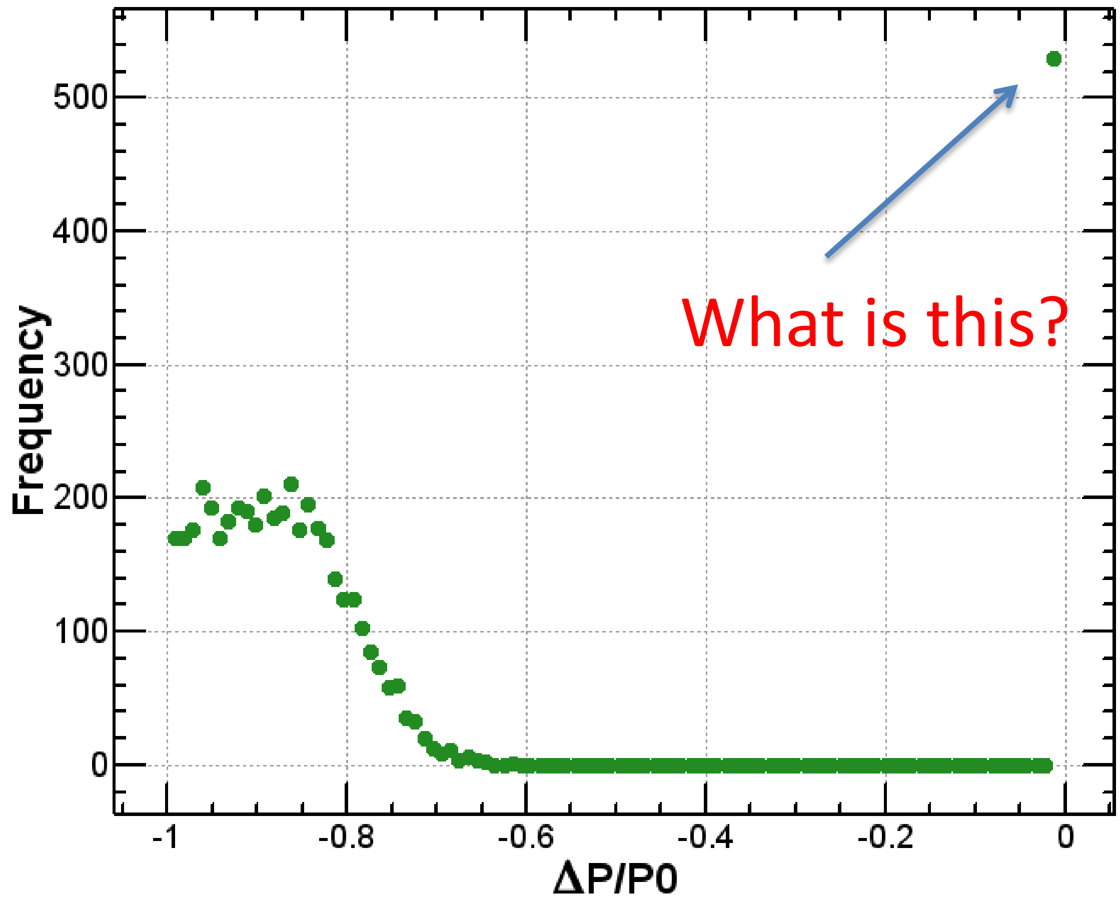
Angular distribution of lost particles
-4m < s < 4m



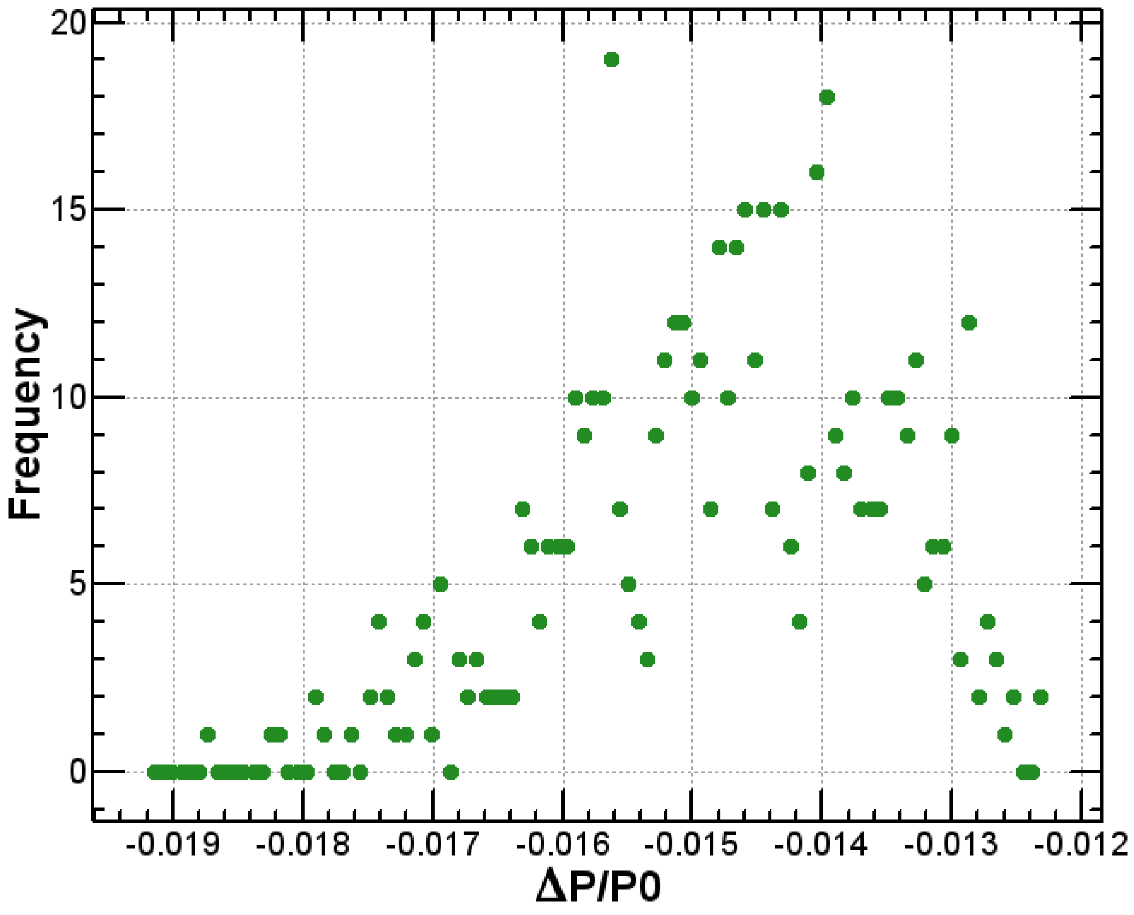
Energy distribution of initial events



Energy distribution of lost particles
-4m < s < 4m

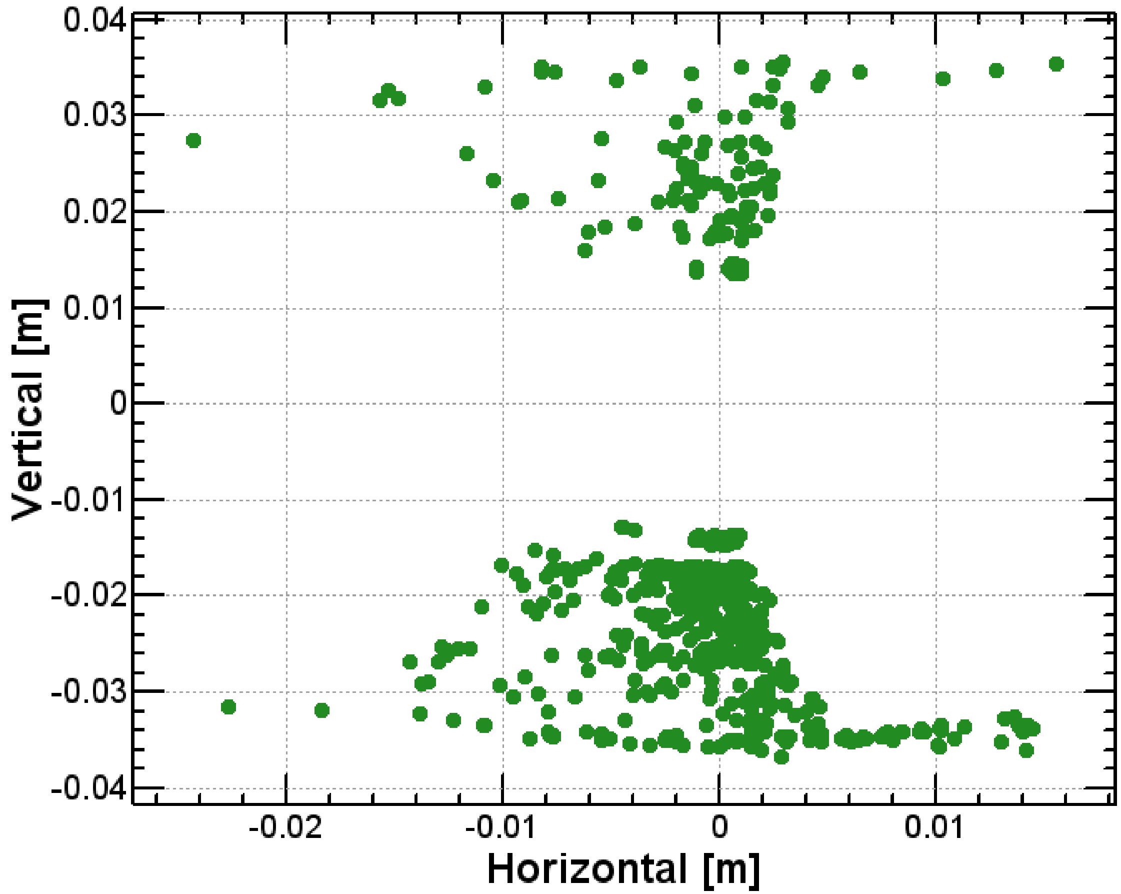


Energy distribution of lost particles
-4m < s < 0m

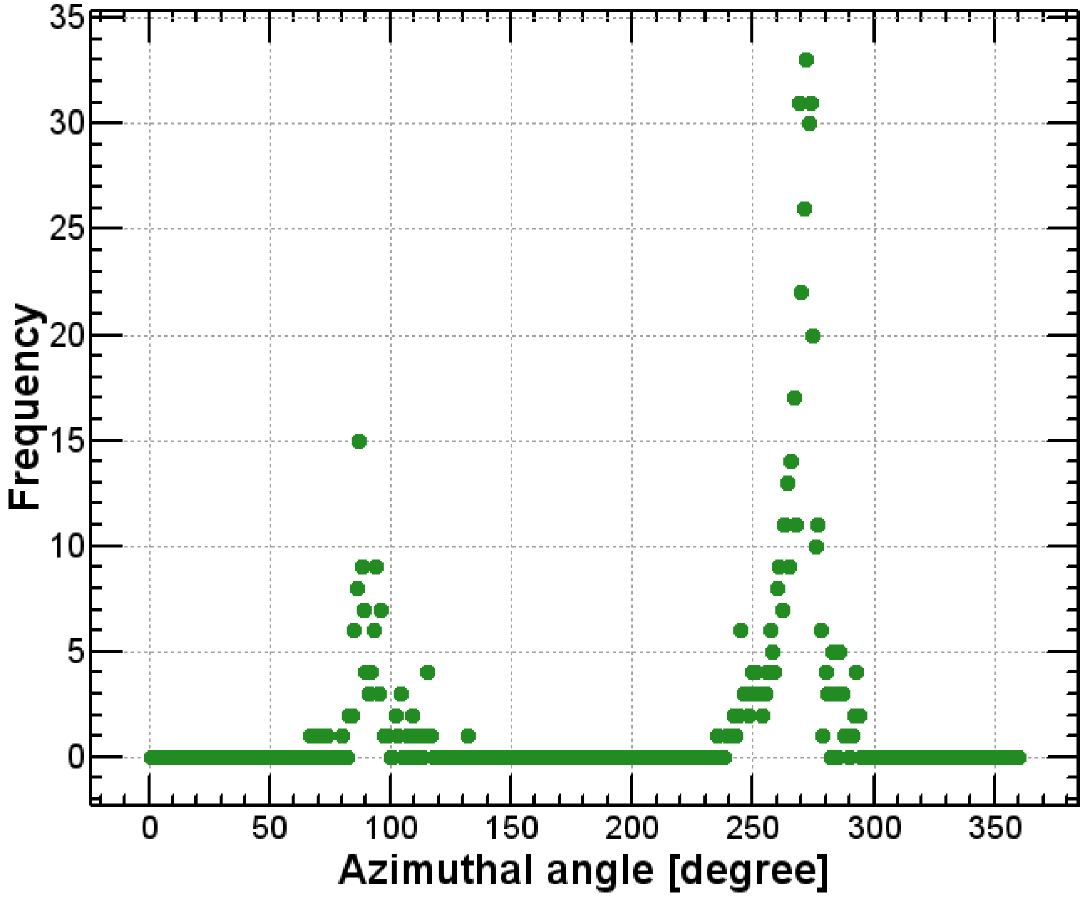


The energy loss of the particles which are lost after almost one turn is very small.

Transverse coordinates of lost particles -4m < s < 0m

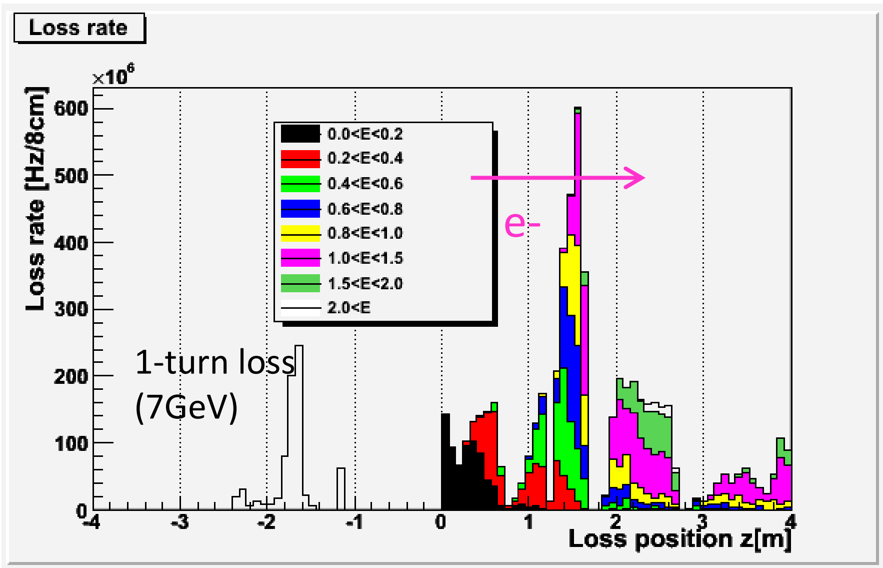


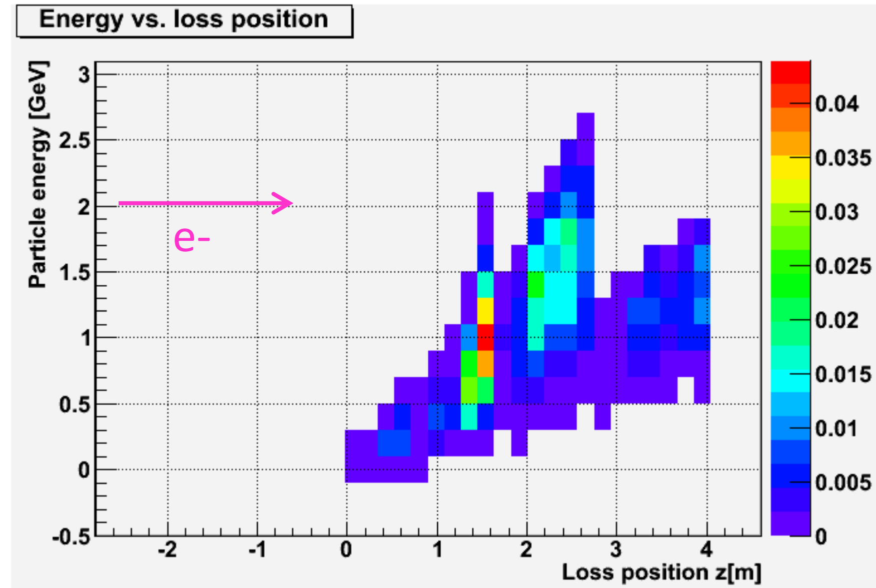
Angular distribution of lost particles
-4m < s < 0m



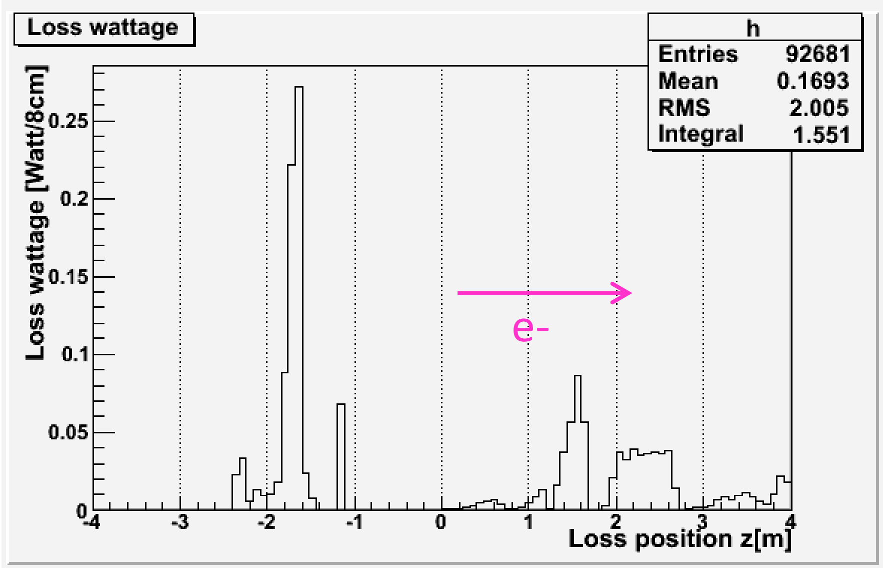
H. Nakayama

Radiative Bhabha HER





W



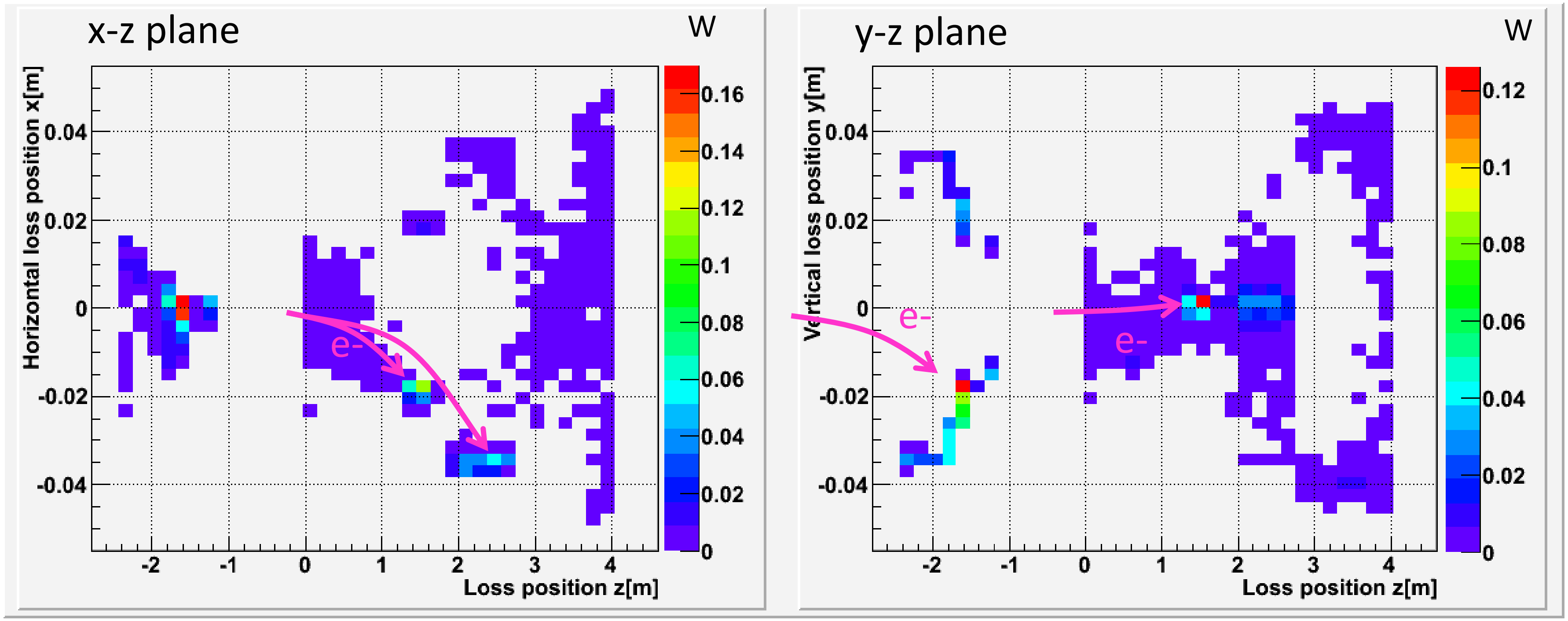
Within |z|<4m,
loss rate: 5.8 GHz(0~2GeV)
loss wattage: 0.75 W
(Equivalent to 0.68GHz of 7GeV e-)

1-turn loss at z=-1.8m
0.72GHz, 0.8W

Loss wattage: we assume all energy of beam particle is deposited at the loss position.

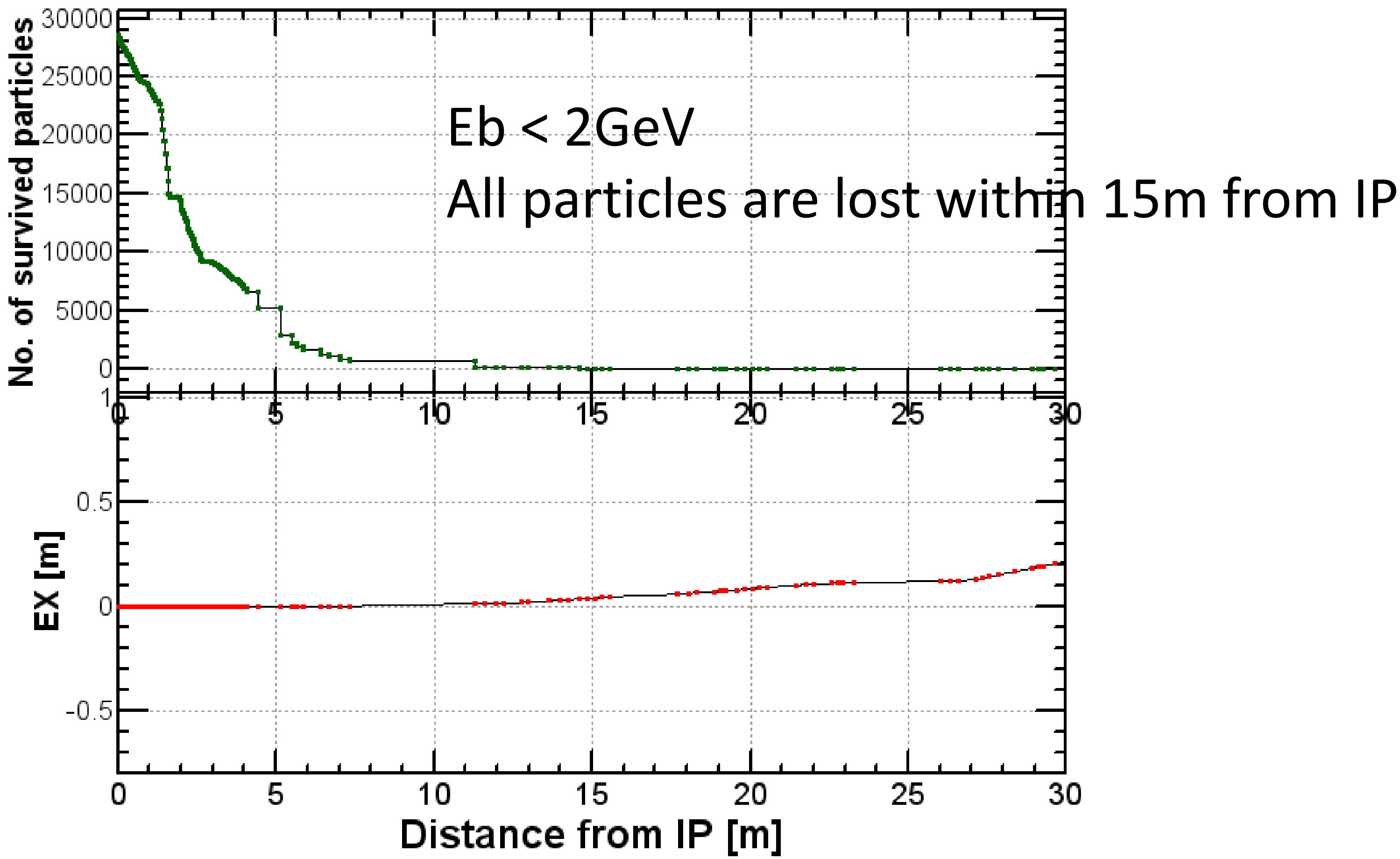
H. Nakayama

Radiative Bhabha HER (contd.)



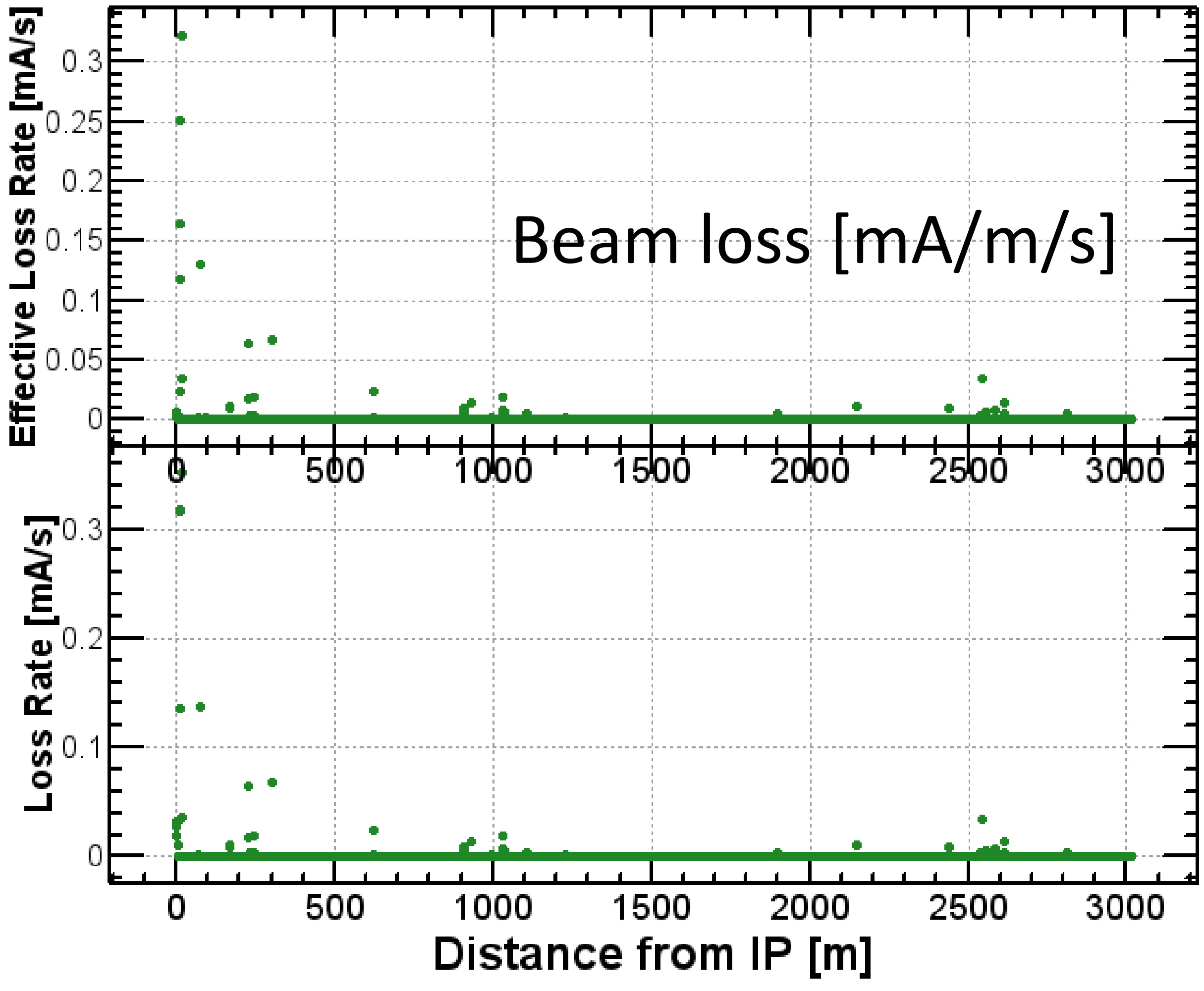
Horizontally lost at z=1.5m
Vertically lost after 1 turn at z=-1.8m

HER: Beam loss with data of BBbrems



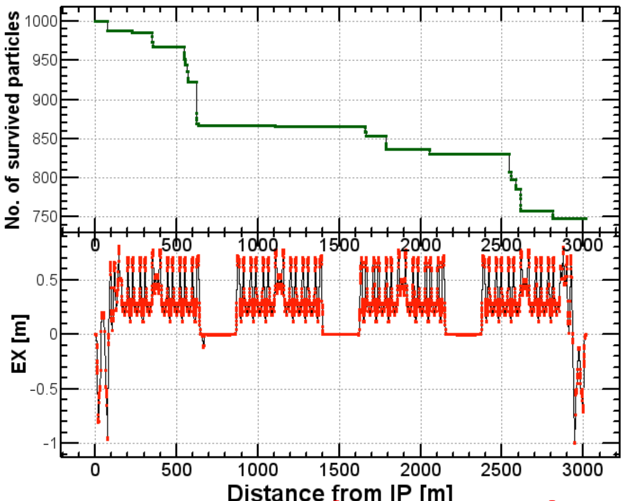
CoordinateBeamLoss2012_2_7_13_51_6.dat

LER: Beam loss around the ring (lerfqlc_1633_3)

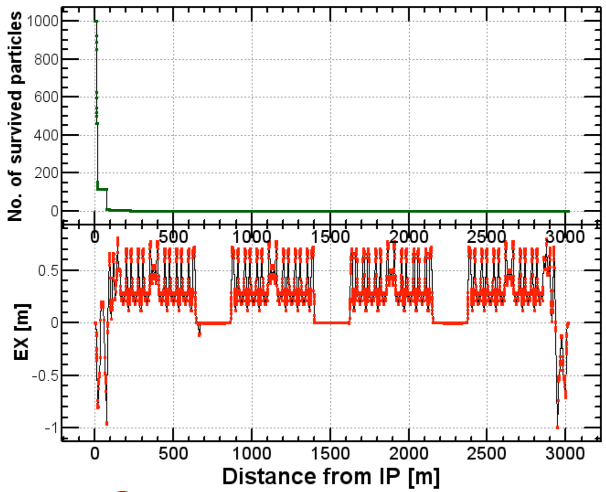


No COD (lerfqlc_1604.sad)

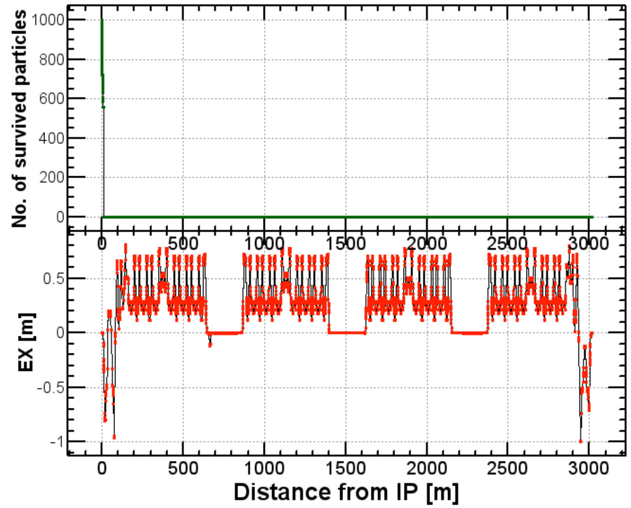
0.2% < ΔE < 4%



4% < ΔE < 40%



40% < ΔE



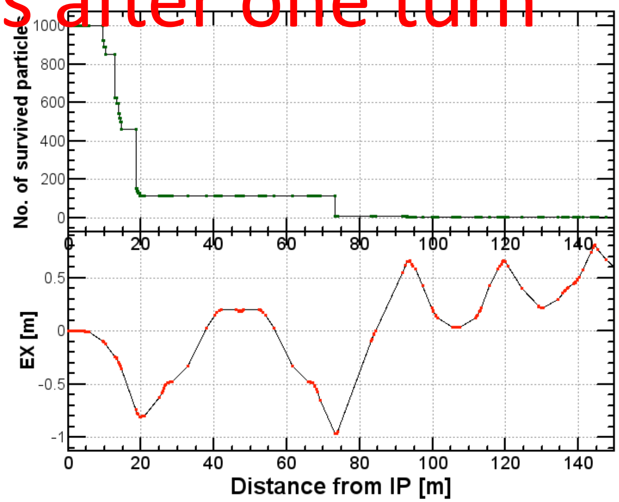
No beam loss after one turn

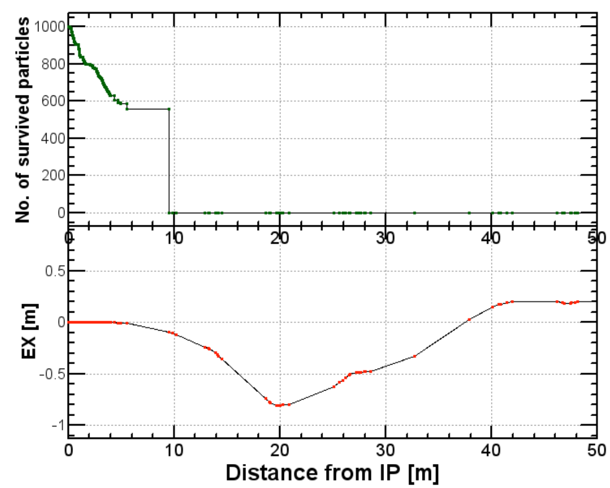
Loss Rate = 116.5GHz

Effective Loss Rate = 91.3GHz

BG Rate in IR (< 4m) = 8.01GHz

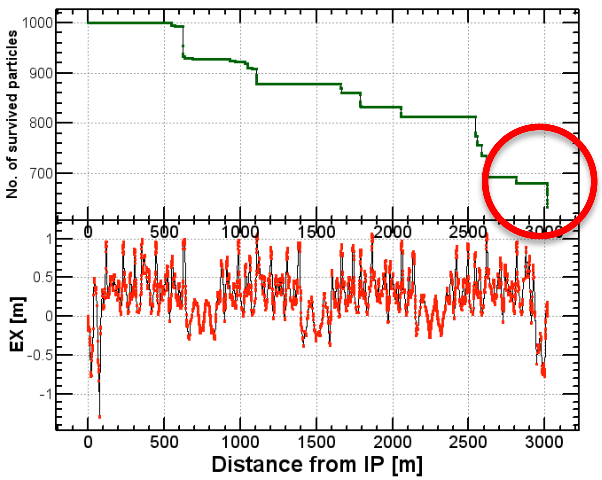
Effective BG Rate in IR (< 4m) = 1.18GHz



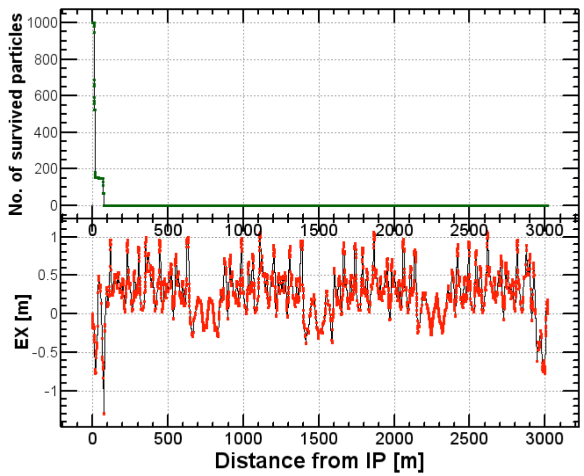


With COD $\Delta x' = 5\sigma_x' \Delta y' = 5\sigma_y'$ (lerfqlc_1604.sad)

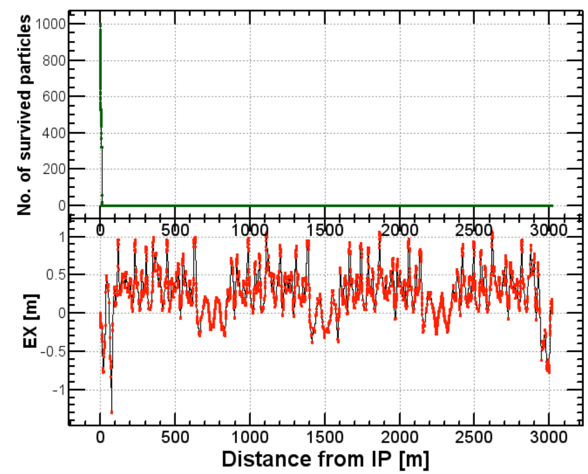
$0.2\% < \Delta E < 4\%$



$4\% < \Delta E < 40\%$



$40\% < \Delta E$

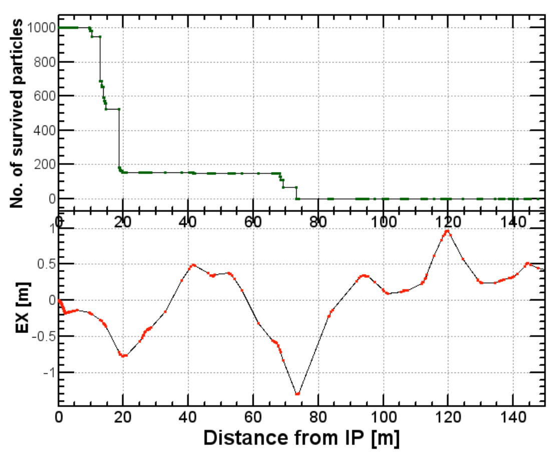


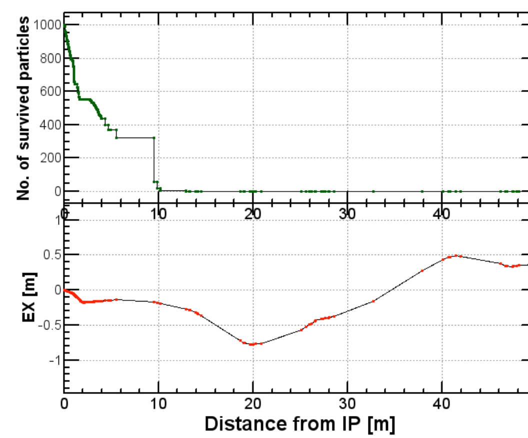
Large amount of beam loss after one turn

Total loss Rate = 121.7GHz
Effective loss Rate = 101.7GHz

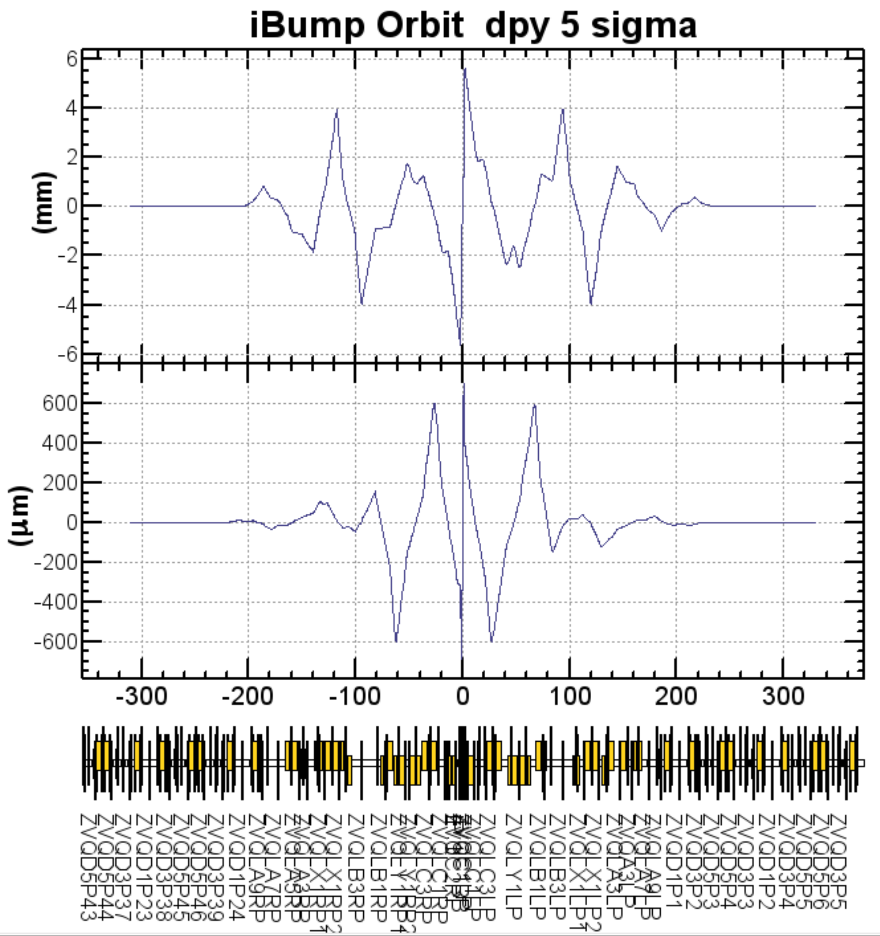
Particel Loss Rate in IR (< 4m) = 12.2GHz
Effective Loss Rate in IR (< 4m) = 2.59GHz

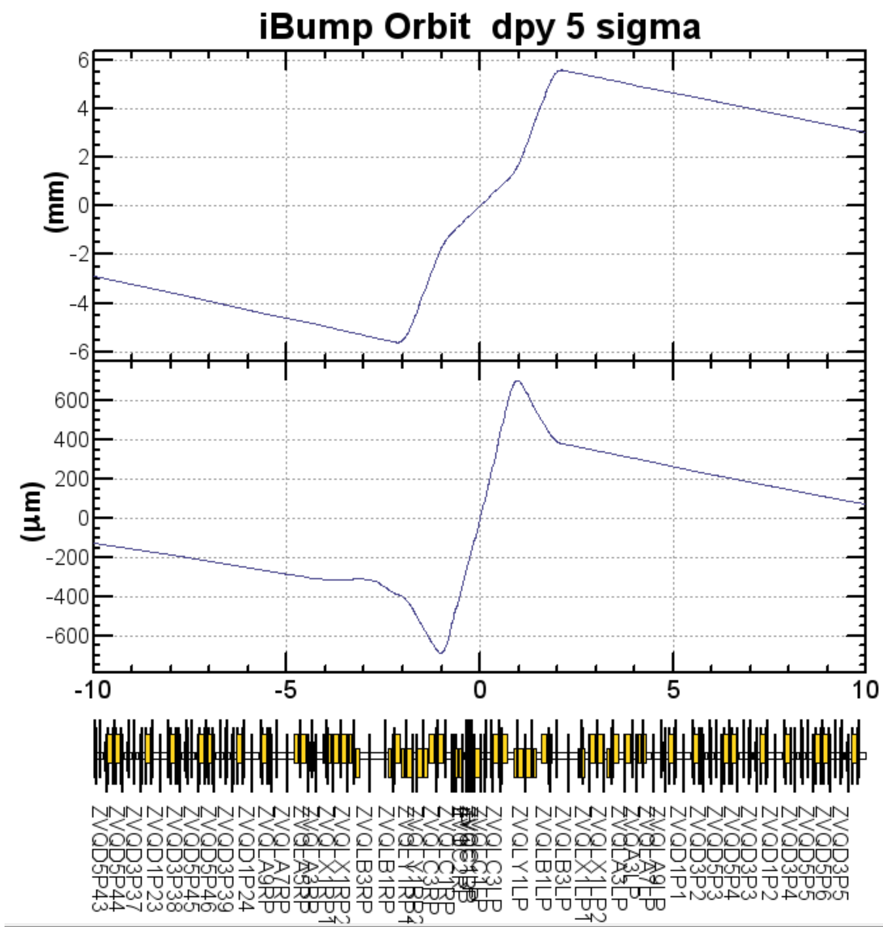
Particel Loss Rate in IR (> -4m) = 4.1GHz
Effective Loss Rate in IR (>- 4m) = 4.0GHz





LER iBump orbit $\Delta x'=5\sigma_x' \Delta y'=5\sigma_y'$





iBump is used for maintaining an optimum beam collision.

Summary

- The beam loss from radiative Bhabha process has been simulated.
- Latest results on beam loss in IR (± 4m from IP) are 0.56W (LER) and 1.56W (HER).
  - Coordinates of lost particles are transferred to Nakayama-san for Belle II background simulation.
- In case of HER, we found that the particles which loss 1 ~ 2% of their energy are lost after almost one turn travelling around the ring.
- Similar loss was found also in LER with large COD (closed orbit distortion).

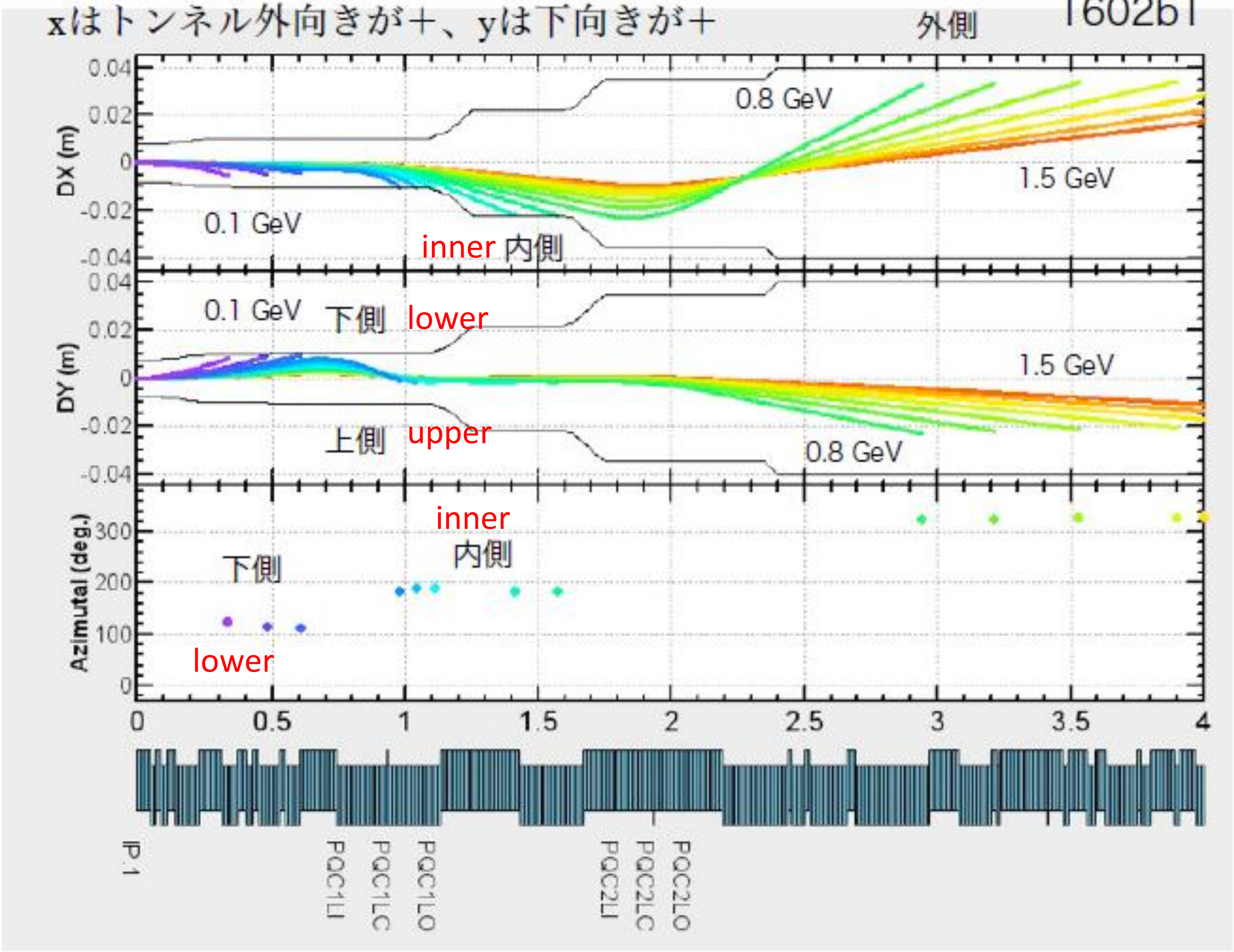
Works to be done

- Tracking with larger number of samples
- To consider the method to reduce particle loss after one turn mainly in HER
- To check if there are multi-turn loss with beam-beam effects
- More systematic study on the effect of closed orbit distortion

LER

Y. Ohnishi

x : positive=ring outer, y: positive=downward



HER

Y. Ohnishi

x : positive=ring outer, y: positive=downward

xはトンネル外向きが＋、yは下向きが＋

5710c(ビームライン裏返し)